BIONOMICS AND LIFE-HISTORY OF GASTRIMARGUS TRANSVERSUS THUNB. (Orthoptera : Acrididæ) UNDER CONSTANT ECOLOGICAL FACTORS

DISSERTATION

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By

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This is to certify that the dissertation for M.Phil. in Zoology has been completed by Mr. Qamar Majeed under my supervision. It is original in nature and I have permitted the candidate to submit it for the award of M.Phil. degree in partial fulfilment of the M.Phil. requirements in Zoology.

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C O N T E N T S

I. INTRODUCTION

Grasshoppers belong to the family Acrididae of the Order Orthoptera. Orthopteroid insects cause considerable damage to agriculture as their nymphal instars and adults voraciously feed on the green vegetation. They have got world-wide distribution and there is no tract of land with green vegetation where these pests do not damage the crops. Although a large number of these pests have been controlled, but still there are many destructive grasshoppers which have to be controlled. Gastrimargus transversus Thunb. is one of them.

The present work is an attempt to study the biological, behavioral and certain morphological observations of G. transversus Thunb. G. transversus Thunb. occurs throughout tropical Africa, Sudan, South Africa, United Provinces, Nepal, Baltistan, Shevoroy Hills, Java, Celebes, Sylhet (Bangla Desh) and India. In India, it is distributed in West Bengal, Madras, Assam, Kashmir, Ladak, Garhwal, Aligarh and other districts of U.P.

The nymphal instars and adults of G. transversus Thunb. have been found to feed on different crops, such as Zea mays (Maize), Sorghum vulgare (Juar), Oryza sativa (Paddy), Triticum aestivum (wheat), Saccharum officinarum (Sugarcane), Pennisetum typhoides (Bajra). Among weeds they have been recorded on Cynodon dactylon, Setaria verticillata, Echinochloa colonum,

Hemarthria compressa, Sorghum halepense, Solanum nigrum etcetera. Apart from these plants they have also been recorded from vegetable crops, fruit plants, timber plants, cotton fields and nursery plants etcetera.

Nymphal instars and adults of this pest readily attack the germinating as well as the tender stages of the crops and vegetables. They feed voraciously on the seedlings and the tender shoots causing considerable damage.

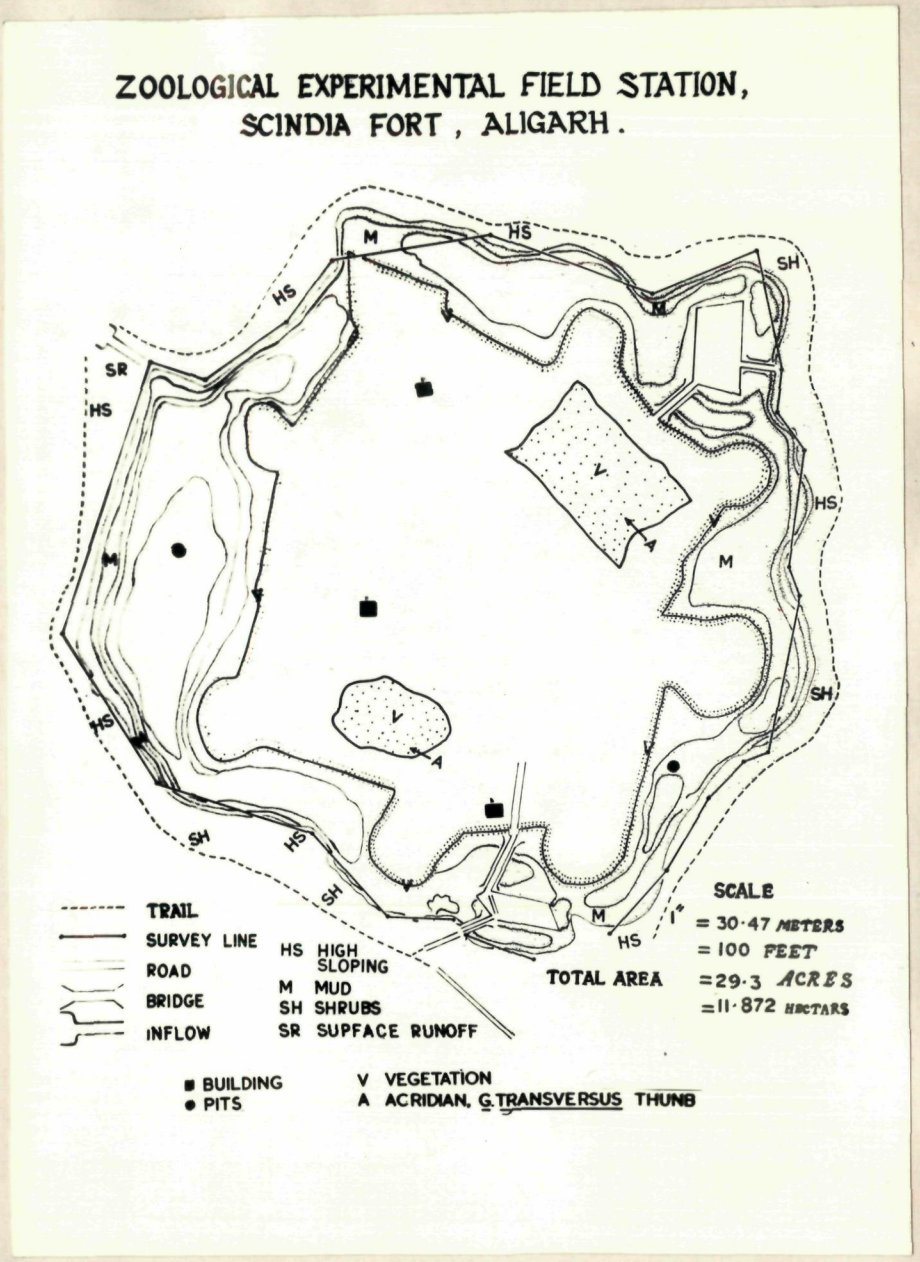
Now adays the extant of the damage by this pest has increased so far that it has become a pest of considerable economic importance.

The biological studies on the acridid pests started in the early twentieth century and considerable work has been done on various acridid pests. Notable contributions have been made by previous authors on the bionomics and life-history of various acridid pests, but no work has been done on the bionomics and life-history of this species. However, some information is available on allied species of Gastrimargus. Chesler (1938) made studies on G. wahlbergii Stal., and Common (1948) on G. musicus Fabr Hunter-Jones and Ward (1959) published a paper on the life-history of G. africanus Saussure.

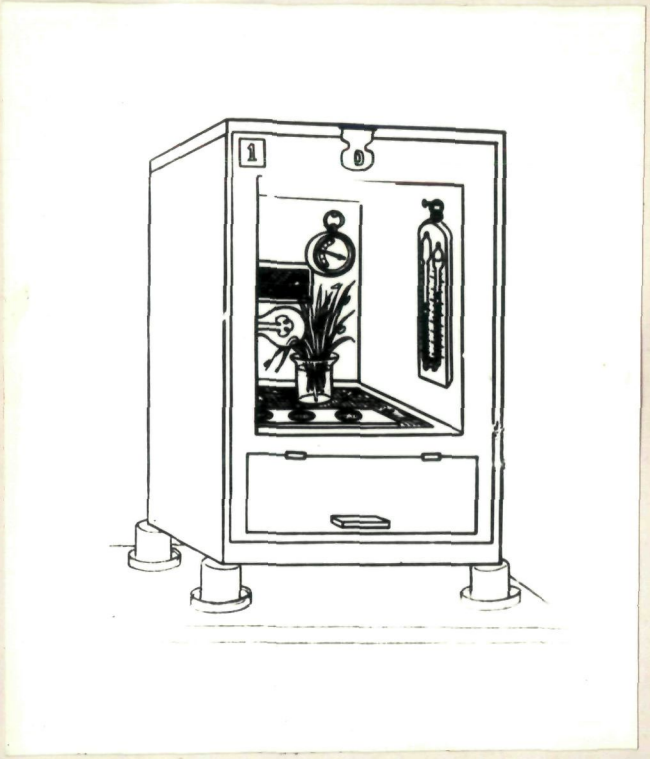
In the present study, an attempt has been made to study the bionomics and life-history of this pest.

II. MATERIAL AND BREEDING TECHNIQUES

In order to maintain the stock, adult males and females of Gastrimargus transversus Thunb. were collected in November, and December, 1974, from Bamboos, maize, bajra, cabbage and grass-fields in and around the Zoological Experimental Field Station, Scindia Fort, A.M.U. Aligarh (Plate I) and were kept in wooden cages (Plate II). Each wooden cage measured 58 x 40 x 36 cm. All the three sides of the cage were made of wood while the front side was divided into two parts - the upper and the lower. The upper part made of glass was fixed, measuring 31 x 31 cm, and the lower portion, measuring 31 x 12 cm, was made of wood forming a window for cleaning the faecal matter. The back side of the cage contained a window fitted with wire-gauze for ventilation. The whole cage is divided into two portions by a flase-floor, made of wire-gauze fitted at about 36 cm from the top of the cage. On one side, the false floor was provided with 3 holes, each measuring 3.5 cm in diameter, for the insertion of the metallic tubes, each measuring 10.7 cm in length and 3.3 cm in diameter. The roof is made of wood and hinged on the backside. The roof of the cage was also provided with a window, measuring 12 x 12 cm in size, for releasing the grasshoppers and grasses etcetera. A socket with an electric bulb was provided on the left side of the cage for maintaining temperature and light. A



Map of Zoological Experimental Field Station Scindia Fort, Aligarh.



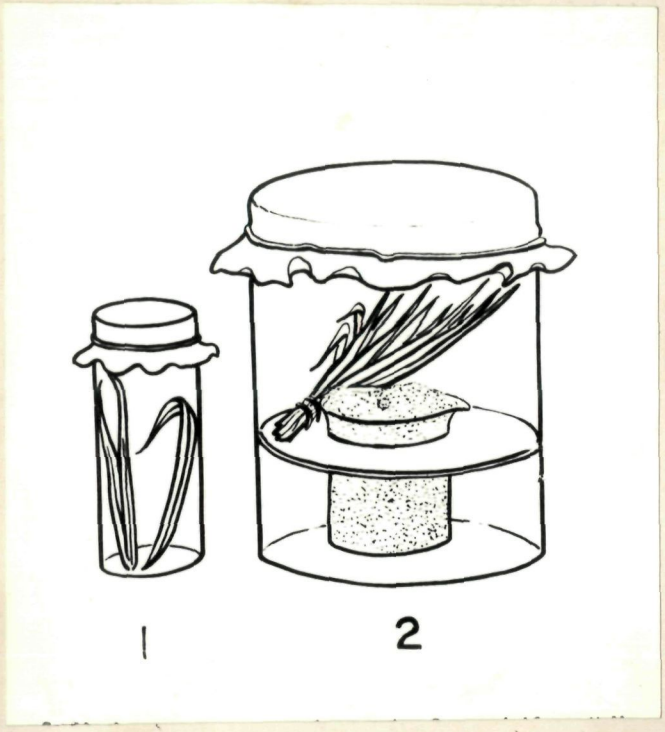
Wooden cage used for rearing G. transversus Thunb.

minimum and maximum thermometer was hung on the right side of the cage and on the backside a hair hygrometer was suspended. The metallic tubes, filled with sterilised sand moistened uniformly with distilled water were inserted into the holes for oviposition. The temperature inside the cage was maintained at 32 ± 5°C by using electric bulbs of different wattage (15, 25, 40, 60 Watts etc.). The relative humidity was maintained at 65 ± 5% by potassium hydroxide solution in a petridish placed below the false floor of the cage.

The bundles of cutweed, Cynodon dactylon, placed in a little quantity of water in a beaker of 100 ml were supplied daily in the morning at an interval of 24 hours.

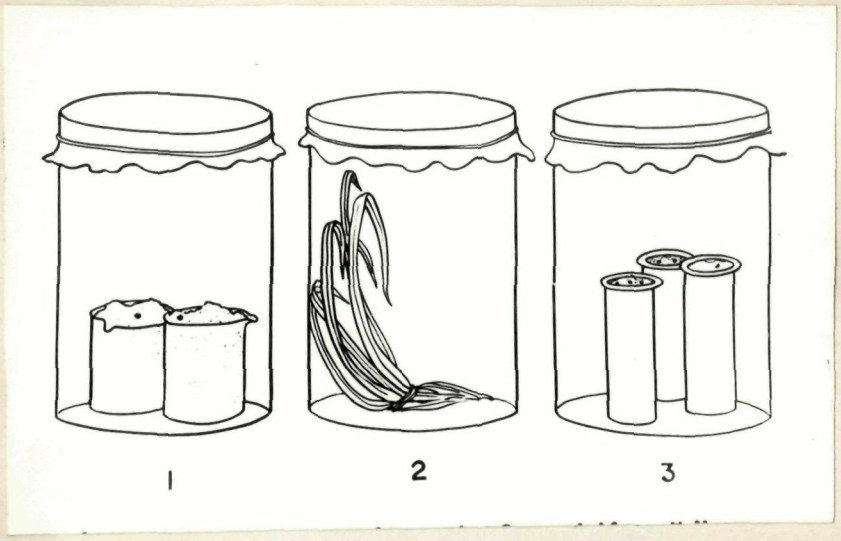
In order to obtain the eggs, the adult males and females were kept in pairs in large glass jars (Plate III, Fig. 2) measuring 15 x 21 cm. A circular piece of wire-gauze measuring 15 cm in diameter with a hole (5.5 cm in diameter) in the centre was placed in each large glass jar at a distance of 8 cm from the bottom. A beaker of 100 ml filled with moist sterilised sand was inserted into the hole of the wire gauze for egg-laying. Food was supplied daily in the morning after 24 hours. These glass jars were placed in constant temperature room at 32 ± 1°C and 65 ± 5% R.H.

The egg-pods obtained from the cages and glass jars were then placed in large glass jars, measuring 15 x 21 cm (Plate IV,



Large glass jar and glass tube used for rearing

G. transversus Thunb.



Large glass jars used for rearing G. transversus Thunb.

Figs. 1 & 3), covered with muslin cloth tied with rubber band, and placed in the incubator at 32 ± 1°C and 65 ± 5% R.H. for incubation or in a refrigerator at 14 ± 1°C for storage. The egg-pods placed in the incubator were moistened with distilled water according to the need. The newly hatched hoppers were transferred into large glass jars, measuring 15 x 21 cm (Plate IV, Fig. 2). The glass jars were covered with muslin cloth and placed in a constant temperature room at 32 ± 1°C and 65 ± 5% R.H., fresh leaves of C. dactylon were supplied as food at an interval of 24 hours. Later on the adults were transferred into the wooden cages.

To study the number of hopper instars, the newly hatched hoppers were reared in isolation in glass tubes, measuring 10.2 x 3.7 cm (Plate III, Fig. 1). The mouth of the tube was covered with muslin cloth and tied with rubber band, leaves of C. dactylon were placed inside the tube regularly every 24 hours. The glass tubes were also placed in constant temperature room at 32 ± 1°C and 65 ± 5% R.H. In constant temperature room 12 hours' light altered with 12 hours darkness.

When there was no egg laying, the egg-pods stored in the refrigerator were taken out and placed in the incubator for incubation to obtain the hoppers.

III. BIONOMICS AND LIFE-HISTORY UNDER CONSTANT ECOLOGICAL FACTORS

(1) REVIEW OF LITERATURE:

Considerable amount of work has been done to study the bionomics and life-history of various acridid pests. Notable contribution in this field has been made by previous authors. Faure (1923) studied the bionomics and life-history of Locusta pardalina (brown locust), Johnston (1926) on Schistocerca gregaria Forsk. Criddle (1933) on Schistocerca lineata, Ivanov (1934) on Oedaleus decorus, Husain and Ahmad (1936a,b) on Schistocerca gregaria Forsk., Zoheiry (1937) on Anacridium aegyptium, Pruthi and Nigam (1939) on Poecilocerus pictus Fab., Latif and Haq (1951) on Chrotogonus robertsi, Burnett (1951) on Nomadacris septemfasciata Serv., Katiyar (1955) on Aularches punctatus, Agrawal (1955) on Atractomorpha crenulata, Antoniou and Hunter-Jones (1956) on Eyprepocnemis capitata Miller and Eyprepocnemis plorans ornatipes Walk (1958), Katiyar (1956) on Parahieroglyphus bilineatus Bol., Dudley (1961) on locust, Pradhan and Peswani (1961) on Hieroglyphus nigrorepletus Bol., Iqbal and Aziz (1973) on Spathosternum parasiniferum Walk., Khan, H.R.(1974, Ph.D. Thesis) on Oedaleus abruptus and Eyprepocnemis alacris Serv.

Pruthi and Nigam (1939) observed in Poecilocerus pictus that male after emergence takes more time to get ready for copulation whereas female copulates just after emergence. Iqbal and

Aziz (1973) also made similar observations in S. parasiniferum Walk. During copulation the male mounts on the back of the female, the penis is then introduced between the ventral ovipositor valves of the female into the vagina and its tip reaches the spermathecal duct. This has been observed in Anacridium aegyptium (Fedorov, 1927), Locusta migratoria (Boldyrev, 1929) and Melanoplus differentialis (Kyl, 1938). This type of copulating posture is found in those species where males are smaller than females. Uvarov (1966) gave a detailed account of the common mode of copulation in acridid (Mode I or riding mode of present account) in Schistocerca gregaria. The copulating posture may differ in other species. Jhingran (1944) recorded another mode of copulation (Mode II or lateral mode) in Heteracris capensis Thunb. Katiyar (1952) recorded a third mode of copulation (Mode III or hanging mode) in Parahieroglyphus bilineatus Bol. Katiyar (1956b) observed an intermediate mode of copulation between mode II and mode III in Oedaleus abruptus and Gastrimargus transversus Thunb.

Hebard (1937) observed in Spaniacris that the female during copulation takes to wings along with the male. In some species e.g., S. gregaria (Popov, 1958), the copulating female may continue to feed, crawl and jump.

The process of oviposition has been described by Fedorov (1927) in Anacridium aegyptium, Pruthi and Nigam (1939) in Poecilocerus pictus, Agrawal (1955) in Atractomorpha crenulata,

Katiyar (1955) in Aularches punctatus, Hafiz and Ibrahim (1958) in Acrida pellucida, Iqbal and Aziz (1973) in Spathosternum parasiniferum Walk., and Khan, H.R. (1974, Ph.D. Thesis) in E. alacris and O. abruptus. It has been observed that the eggs are laid in burrows made in the moist soil with the help of the abdomen. In addition to this Rao (1921) observed that the female of Oxya velox may also lay eggs on the foliage of the plants in the water-logged fields and in the laboratory. Joyce (1952) studied the soil conditions preferable for oviposition of S. nigrotaesiatum. Norris (1950, 1952) studied the effect of crowding on preoviposition period and interval of successive egg-laying of African migratory locust and Desert locust. Antoniou and Hunter-Jones (1956) studied the effect of crowding on the fecundity of E. capitata Mill., also Hunter-Jones and Ward (1959) studied the effect of crowding on sexual maturation of females, egg-laying rate, fecundity and viability of eggs of G. africanus Sauss.

Roonwal (1936a) studied the gradual increase in the size of eggs during the embryonic development of Locusta migratoria. Similar increase has also been recorded for other species with the exception of highly xerophilous Tmethis, the eggs of which do not change in size (Shulov, 1952d).

Kumashiro (1935) studied the incubation period of the eggs of Oxya velox Fabr. Khan and Aziz (1974) studied the effect of different levels of temperature and humidity on incubation period of eggs of E. alacris Serville.

Extensive description on the hatching process has been given by Kunkel d'Herculais (1890a, 1890b, 1893-1905) for Dociostaurus, Vosselor (1905) and Bernays (1971) for Schistocerca and Mikhelson (1922) for Locusta.

The vermiform larva emerges on the surface of the soil and casts off its outer covering membrane known as the "intermediate moult" (Uvarov, 1966). The individual now resembles in its general appearance to the adult and is called the first instar hopper.

In acridoids the number of nymphal instars may vary from species to species and even in the individuals of the same species. According to Uvarov (1966), the number of instars is inversely proportional to the degree of advancement among the groups of acridoids; thus suggesting an evolutionary trend in the reduction of the number of instars. Kevan (1943) has attributed this variation among nymphal instars for the species in which the sexes differ considerably in size of adults. The duration of nymphal instars is also variable from species to species and within the individuals of the same species. Khan and Aziz (1974) have studied the effect of different levels of temperature and humidity on the nymphal duration of E. alacris Serville.

Several other significant contributions have been made by Singh (1961) and Grewal and Atwal (1968) on Chrotogonous trachypterus Balanchard, Misra (1962) on Camnula pellucida Scudder, Barnes (1963, 1965) on M. differentialis Uhler and M. sanguinipes Fab. respectively.

(2) OBSERVATIONS:

To study the bionomics and life-history of G. transversus Thunb., following four sets of experiments were conducted under constant ecological conditions.

(i) Ten pairs of adult males and females were obtained from the stock. The general body colour of these insects was recorded before killing in the 70% alcohol and morphological studies were undertaken to find out the morphological differences, if any, with its hopper instars as well as other acridoids. The results are included under the sub-heading "distinguishing characters". Similarly different hopper instars were obtained from the stock and preserved in 70% alcohol for the morphological studies along the lines described above. The results are included under the sub-heading "Description of hopper instars".

(ii) Twenty pairs of newly emerged males and females of this grasshopper were obtained from the stock and each pair was kept separately in large glass jar (Plate III, Fig. 2). Arrangement was made for the oviposition in each glass jar. These glass jars were kept in constant temperature room at 32 ± 1°C and 65 ± 5% R.H., where 12 hours' light was altered with 12 hours' darkness. The insects were fed on Cynodon dactylon. Food was changed after every 24 hours. The number of egg-pods were recorded throughout the life of each pair. The eggs were counted in each egg-pod to

obtain the average fecundity. The newly laid eggs were taken and incubated at 32 ± 1°C and 65 ± 5% R.H. The incubation period of these eggs was recorded. Observations on the vermiform larva soon after hatching were also made. The results are presented under the sub-heading - Copulation, Oviposition, Longevity of adults, Egg-pod, Eggs, Hatching, Maturation and egg-laying rate, Fecundity and viability, Vermiform larva.

(iii) To make detailed and extensive observation on the number, duration, colouration of hopper instars, nelwy hatched first instar hoppers were kept in isolation in glass-tubes (Plate III, Fig. 1). These glass tubes were placed in constant temperature room at 32 ± 1°C and 65 ± 5% R.H, where 12 hours' light altered with 12 hours' darkness. The hoppers were fed on Cynodon dactylon leaves. The results are presented under the sub-heading hopper instar.

(iv) To make studies on the effect of crowding on sexual maturation, egg-laying rate, fecundity and viability, twenty five pairs of newly emerged adults were kept under crowded conditions in a wooden cage (Plate II). The insects were fed on C. dactylon leaves after every 24 hours and were kept at 32 ± 1°C and 65 ± 5% R.H. where 12 hours' light altered with 12 hours' darkness. The results are presented under the sub-headings "Sexual maturation and egg-laying rate and Fecundity and viability.

A - ADULT

(i) Distinguishing Characters:

(a) Female.- Body stout, 38-41 mm in length and 6-7 mm in width across the pronotum; colour variable brownish, greenish, with creamy and dark bands and patches on the whole body.

Head.- Hypognathus, 6-7 mm in length and 7-8 mm in width; colour variable light green to brownish; vertex sloping down smoothly between compound eyes; Occelli white, arranged in equilateral triangle; antennae filiform, 14-30 segmented, inserted just above the lower level of the eyes as long as head and pronotum combined; eyes brownish with a white transverse band; behind each eye a pale band runs to the back of the head, bordered above and below with black, which is generally continuous on the front of the pronotum; mandibles dark and strongly sclerotized, apex truncated; maxillary and labial palpi 5 and 4-segmented respectively.

Thorax.- Colour variable, longitudinally or obliquely striped with green, brown and whitish; 11-12 mm in length and 4-8 mm in width. Pronotum with median carina well developed, anteriorly projecting covering posterior part of the head, and acutely angulated behind covering mesonotum and part of the metanotum. The lateral parts of the pronotum form a very distinct angle with its dorsum at its posterior region, and seems to be separated from it by lateral carinae, while at the

anterior region the lateral lobes of the pronotum form a rounded angle with its dorsum.

Forewings.- Forewings (Tegmina) long, narrow and extending much beyond the abdominal apex; anal region light green, remaining tegmina brownish to the middle, with whitish markings, specially a transverse one near the base; the outer half of the tegmina hyaline, generally more or less blotched with brown.

Hindwings.- Shorter than the tegmina, bright sulphur-yellow at the base, with a black central band curving round to the anal angle; beyond this, the wing is hyaline, more or less blackish at the tip.

Legs.- Hind femora long and slender, greenish or yellowish, spotted and dotted with black, and serrulated above, 21-23 mm in length and 6 mm in width; hind tibiae red, often shading into greenish at the base, with 22 tibial spines tipped with black.

Abdomen.- Brownish or reddish brown, 11 segmented, 20-22 mm in length, longer than head and thorax combined; cerci short; ovipositor valves well developed. Tympanal organ well developed.

(b) Male.- Resembles females in general appearence, except being smaller in size, body 22-28 mm in length, head 5-6 mm in length and 7-8 mm in width; thorax 7-8 mm in length and 4.5- 5 mm in width across the pronotum; abdomen 12-13 mm in length; hind femur 16 mm in length and 4.5 mm in width; cerci long and laterally compressed and presence of male genital organs. Antennae 27-29/ segmented.

(ii) Habit:

Adults of Gastrimargus transversus Thunb. assemble in masses on the grasses, bush tops and tree tops upto a height of 15-20 feet to bask in the sun early in the morning. They were found sitting on the leaves of plants, vegetables and fruit plants facing sun rays. They are photopositive and are found to disperse on falling of shadow of a person on them. In the morning when the temperature is low, all the hoppers and adults are lazy, dull and sluggish, but as the temperature rises, they become active and start flying here and there. Adults are usually found to make a low hissing noise when they start flying.

In the early hopper stages, the hoppers feed on tender portion of the soft leaves only. In the initial stage they make small cuts over the leaf lamina leaving the veins and petioles. But in the later stage when they become old they eat all parts of the leaves leaving only petioles. Both the hopper instars and the adults are gregarious and feed voraciously. Hunter-Jones and Ward (1959) in Gastrimargus africanus Sauss. have also observed the gregarious nature of the insect.

When adults or late instar hoppers are caught, they emit a blackish offensive secretion with a pungent smell. Katiyar (1955) has also recorded in Aularches punctatus that this fluid is emitted from:-

1) The thorax close to the base of the hind legs,

2) Base of the front legs and

3) Posterior margin of metanotum.

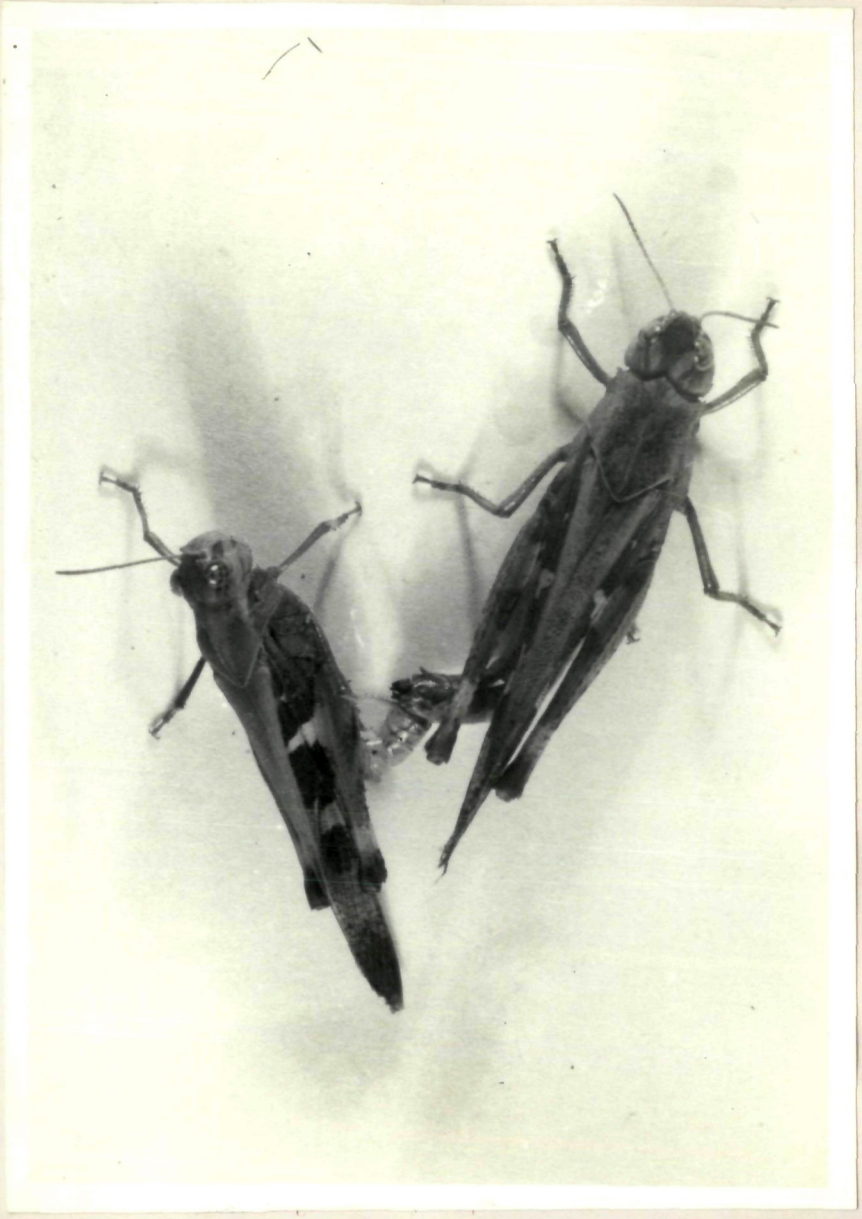
Hingston (1927) observed in A. miliaris that the fluid is usually as clear as water, but sometimes turbid or faint-yellow.

(iii) Copulation:

The following observations were made from the second set of experiments.

The copulation does not start immediately after emergence. Both the males and females do not reach maturity at the same time. The pre-maturation period (Table11) in the males varies from 6-8 days, averaging about 6.8 ± 0.249 days and in females it varies from 7-10 days averaging 8.7 ± 0.338 days. The pre-maturation period of the adults is variable, depending upon temperature, humidity and food.

The process of copulation (Plate V) in Gastrimargus transversus Thunb. is very peculiar and the copulating pairs show all the three modes of copulation as described by Katiyar (1952, 1955). The males and females copulate several times during the life-time. Before copulation, the male and female start jerking their hind legs giving signal for copulation. During copulation male mounts in a dorso-lateral posture on the female, clasping her firmly by the first two pairs of legs,



G. transversus Thunb., copulating pair, showing the mode of copulation.

the third pair does not take part in the process of copulation. The mating can also take place after the removal of hind pair of legs. Sometimes two or three males were seen clasping a single female for copulation. After holding the female firmly, the abdomen of the male is curved downwards and then by a slight twist its tip is brought under that of the female abdomen. At this moment the cerci are raised and the aedeagus is protruded and is inserted between the valves of the female sub-genital plate, ultimately it enters the opening of the spermathecal duct of female.

Somewhat similar observations have been made by Fedorov (1927) in A. aegyptium, Boldyrev (1929) in Locusta, Kyl (1938) in Melanoplus, Gregory (1961) in Locusta.

The present author also observed different postures during the copulation of this grasshopper. During early stages of copulation, the male mounts on the female in dorso-lateral position, but after sometime the copulating pair show lateral posture and at the end of copulation male forms an acute angle with the body of female. When the copulation takes place on the leaf of a plant, hanging posture may be observed. So, G. transversus Thunb. shows considerable intraspecific variation in the mode of copulation. Similar variations have also been recorded by Katiyar (1956b) in G. transversus and O. abruptus.

When copulation is over, the female jerks its hind legs repeatedly. The male is disturbed due to jerks of the female

and leaves the copulating female. The copulation thus comes to an end. Often copulating pairs continue to feed and crawl. This has also been recorded by Popov (1958) in Schistocerca gregaria. Generally copulation lasts for 30-50 minutes.

(iv) Oviposition:

The following observations were made from the second set of experiments.

The females of G. transversus Thunb. oviposit in the moist soil. Sometimes egg-clutch are laid on leaves of the food plant. The pre-oviposition period (Table 1) varies from 5-10 days averaging 6.2 ± 0.533 days. Before oviposition, the females become lazy and are seen either brushing their abdominal tips with the hind tibia or digging the soil with their ovipositors. Katiyar (1955) has also observed similar behaviour in Aularches punctatus Drury. The female of G. transversus Thunb. before egg-laying make a selection of the site by crawling over and tapping the floor with rythmic opening and closing of the ovipositor valves. The antennae and palpi may also help in the selection of site. If suitable site is available, its abdomen bends slightly making an angle of 140° or 150° with the surface of the soil. During the course of boring, the female raises its body on the first two pairs of legs, getting slight support from the hind pair of legs as well. The female bores holes in the sand by extending its abdomen to a depth of 4.0 cm to 6.5 cm.

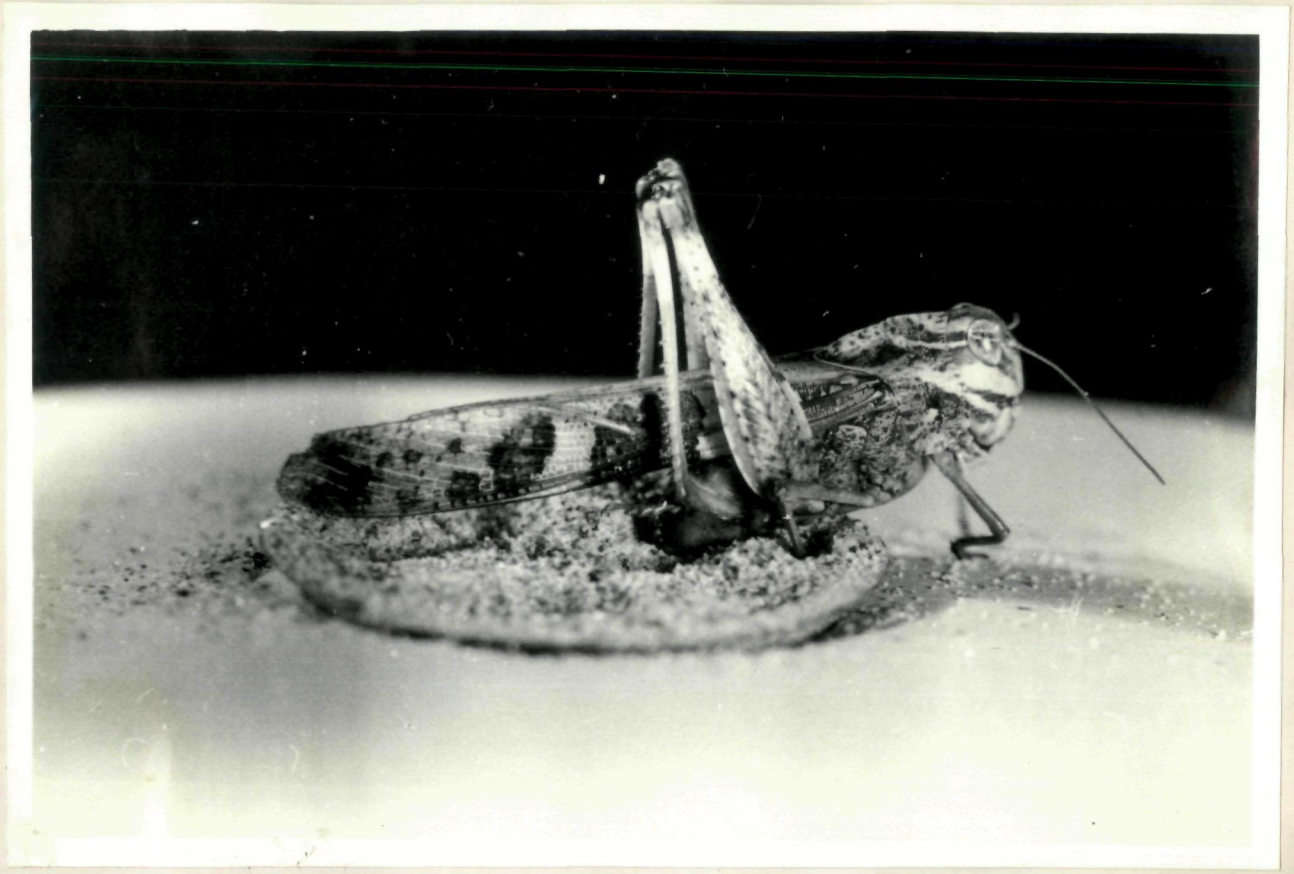
Table 1. The pre-copulation, pre-oviposition, oviposition and post-oviposition periods of females of G. transversus Thunb. reared at 32 ± 1°C and 65 ± 5% R.H., where 12 hours' light altered with 12 hours' darkness, fed on C. dactylon leaves.

Experiment No.	Pre-copulation period (Days)	Pre-oviposition period (Days)	Oviposition period (Days)	Post-oviposition period (Days)
1	9	6	23	4
2	10	7	17	3
3	10	10	18	1
4	9	5	17	3
5	7	5	6	1
6	9	6	16	3
7	9	5	15	1
8	8	5	15	1
9	7	8	22	2
10	9	5	20	1
Average	8.7	6.2	16.9	2.0
± S.E.	± 0.338	± 0.533	± 1.493	± 0.421

S.E. = Standard Error

During boring, the rhythmic opening and closing of the ovipositor valves along with gradual backward crawling helps the abdomen to go deeper and deeper. The depth of the holes in Anacridium aegyptium varies from 3.5 to 9-10 cm (Fedorov, 1927), in Acrida pellucida varies from 4.5 cm to 15-17 cm (Hafez and Ibrahim, 1958), in Aularches punctatus varies from 2.6 to 7.7 cm (Katiyar, 1955) and in Atractomorpha crenulata from 8 to 10 cm (Agrawal, 1955). The depth of the holes depends upon the extension of the abdomen (Uvarov, 1928, 1966).

After making two or three trial holes, when they are ready the female inserts its abdomen (ovipositor) with a jerk, to lay the eggs (Plate VI). A frothy secretion of accessory glands is emitted which is absorbed by the sand. This frothy secretion is hardened to form the wall of the egg-pod. A part of the frothy secretion is deposited at the bottom of each egg-chamber about 0.1 to 0.2 cm in thickness. After this the actual egg-laying commences. The eggs are propelled by pulsating movements of seventh and eighth sternites, when an egg approaches the exit of the ovipositor its valves open widely and egg comes out between the ventral and the inner valves. Finally the pulsatile movements of the terminal segments are resumed, more frothy secretion is emitted and the eggs are laid with frothy lamellae in between. The emission of this secretion continues till all the eggs are laid down. The abdomen gradually contracts at each egg laying, when all the eggs are laid, the upper portion



G. transversus Thunb. in the act of oviposition.

of the hole is filled with the froth forming the plug of the egg-pod. The act of oviposition lasts for about 30-60 minutes. After the oviposition almost all the females were seen levelling the holes on the surface of the soil with the aid of the ovipositor valves and the hind legs. After oviposition, the female appears to be exhausted and starts feeding voraciously.

The pre-oviposition period varies from 5-10 days, the oviposition period varies from 6-23 days and the post-oviposition period varies from 1-4 days. The average of pre-oviposition, oviposition and post-oviposition periods are 6.2 ± 0.533; 16.9 ± 1.493 and 2.0 ± 0.421 days respectively (Table 1). The number of egg-pods laid by a single female varies from 2-7, averaging 4.1 ± 0.457 (Table 2).

(v) Sexual maturation and egg-laying rate:

The following observations were made from the second and fourth sets of experiments:

Out of twenty isolated females, three females died before sexual maturation (oviposition). In the remaining seventeen isolated females, the average duration between the emergence and the first oviposition was 15.5 ± 0.507 days (range - 13-19 days), and after maturation, the average interval between the successive egg-laying was 3.85 ± 0.263 days (range - 2-9 days) representing about 2 egg pods per week. The total number of egg-pods laid by a single female varied from 2-7, averaging 4.1 ± 0.457 pods per

he maturation period and interval between the successive egg-laying of G. transversus Thunb. eared in isolation at 32 ± 1°C and 65 ± 5% R.H., where 12 hours' light altered with 12 hours' arkness, fed on C. dactylon leaves.

Date of I egg-laying	Date of II egg-laying	Duration between I & II egg-laying (days)	Date of III egg-laying	Duration between II & III egg-laying (days)	Date of IV egg-laying	Duration between III & IV egg-laying (days)	Date of V egg-laying	Duration between IV & V egg-laying (days)	Dt. of VI egg-laying	Durt. bet. V &VI egg-laying (days)	Dt. of VII egg-laying	Durt. bet. VI & VII egg-laying (days	Total no.of egg-pod laid/ female	Average interval between successive egg-laying
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.6.75	21.6.75	3	25.6.75	4	28.6.75	3	-	-	-	-	-	-	4	3.33
18.6.75	22.6.75	4	-	-	-	-	-	-	-	-	-	-	2	4.00
22.6.75	26.6.75	4	29.6.75	3	4.7.75	5	9.7.75	5	-	-	-	-	5	4.25
19.6.75	23.6.75	4	26.6.75	3	28.6.75	2	2.7.75	4	-	-	-	-	5	3.25
27.6.75	30.6.75	3	3.7.75	3	-	-	-	-	-	-	-	-	3	3.00
27.6.75	1.7.75	4	4.7.75	3	7.7.75	3	11.7.75	4	14.7.75	3	19.7.75	5	7	3.66
27.6.75	30.6.75	3	9.7.75	9	15.7.75	6	-	-	-	-	-	-	4	6.00
26.6.75	1.7.75	5	-	-	-	-	-	-	-	-	-	-	2	5.00
28.6.75	1.7.75	3	5.7.75	4	9.7.75	4	11.7.75	2	-	-	-	-	5	3.25
28.6.75	2.7.75	4	5.7.75	3	-	-	-	-	-	-	-	-	3	3.50
30.6.75	5.7.75	5	7.7.75	2	-	-	-	-	-	-	-	-	3	3.50
2.7.75	4.7.75	2	7.7.75	3	10.7.75	3	13.7.75	3	-	-	-	-	5	2.77
4.7.75	8.7.75	4	10.7.75	2	-	-	-	-	-	-	-	-	3	3.00
1.7.75	4.7.75	3	7.7.75	3	10.7.75	3	14.7.75	4	-	-	-	-	5	3.25
5.7.75	10.7.75	5	14.7.75	4	17.7.75	3	-	-	-	-	-	-	4	4.00
-	- -	-	-	-	-	-	-	-	-	-	-	-	-	-
4.7.75	12.7.75	8	15.7.75	3	-	-	-	-	-	-	-	-	3	5.50
-	- -	-	-	-	-	-	-	-	-	-	-	-	-	-
10.7.75	16.7.75	6	19.7.75	3	24.7.75	5	27.7.75	3	1.8.75	5	5.8.75	4	7	4.33

female (Table 2).

In the cage, where 25 pairs were kept under crowded condition , three females died before oviposition. In the remaining twenty two crowded females, the average duration between emergence & first oviposition was 15.00 ± 0.826 days (range - 10-19 days). In each case the female was labelled by a special distinguishing mark as described by Hunter-Jones and Ward (1959). By examining the ovipositor of each female every day for traces of frothy secretion of the accessory gland, it was possible to infer the time of egg-laying. It was found that the average interval between the successive egg-laying was about 3.57 ± 0.132 days (range - 2-6 days) and 2 egg-pods per week per female were recorded to have been laid. The total number of egg-pods laid by a single female varied from 2-5, averaging 3.81 ± 0.302 egg-pods per female (Table 3).

It is evident from above observations that crowding does not play any important role in the sexual maturation and egg-laying rate, which was found to be approximately similar under isolated and crowded conditions. Similar observations have been recorded by Hunter-Jones and Ward (1959) in the allied species - G. africanus Sauss. where the prematuration period was 19.2 days for both isolated and crowded females and the interval between the successive egg-laying was 4.1 and 4.0 days for isolated and crowded adults respectively, representing about 2 egg-pods per female per week in both cases. Experiments have

The maturation period and interval between the successive egg-laying of G. transversus Thunb. reared under crowded condition at 32 ± 1°C and 65 ± 5% R.H., where 12 hours' light altered with 12 hours' darkness, fed on C. dactylon leaves

Maturation period (days)	Date of I egg-laying	Date of II egg-laying	Duration between I & II egg-laying (days)	Date of III egg-laying	Duration between II & III egg-laying (days)	Date of IV egg-laying	Duration between III & IV egg-laying (days)	Date of V egg-laying	Duration between IV & V egg-laying (days)	Total no. of egg-pods laid/female	Average interval between successive egg-laying
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
14	17.6.75	20.6.75	3	22.6.75	2	28.6.75	6	-	-	4	3.66
17	20.6.75	24.6.75	4	22-6.75	-	-	-	-	-	2	4.00
14	17.6.75	20.6.75	3	22.6.75	2	26.6.75	4	1.7.75	5	5	3.50
17	20.6.75	23.6.75	3	27.6.75	4	1.7.75	4	4.7.75	3	5	3.50
12	15.6.75	17.6.75	2	19.6.75	2	-	-	-	-	3	2.00
13	16.6.75	20.6.75	4	-	-	-	-	-	-	2	4.00
13	16.6.75	21.6.75	5	25.6.75	4	-	-	-	-	3	4.50
11	14.6.75	17.6.75	3	22.6.75	5	25.6.75	3	27.6.75	2	5	3.25
17	20.6.75	23.6.75	3	26.6.75	3	1.7.75	5	-	-	4	3.66
18	21.6.75	23.6.75	2	29.6.75	6	2.7.75	3	-	-	4	3.66
10	13.6.75	16.6.75	3	19.6.75	3	-	-	-	-	3	3.00
14	17.6.75	20.6.75	3	23.6.75	3	28.6.75	5	2.7.75	4	5	3.75
19	22.6.75	25.6.75	3	28.6.75	3	2.7.75	4	-	-	4	3.33
15	18.6.75	22.6.75	4	25.6.75	3	27.6.75	2	-	-	4	3.00
16	19.6.75	22.6.75	3	26.6.75	4	30.6.75	4	-	-	4	3.66
18	21.6.75	26.6.75	5	28.6.75	2	2.7.75	4	-	-	4	3.66
18	21.6.75	24.6.75	3	30.6.75	6	4.7.75	4	3.7.75	3	5	4.00
14	17.6.75	20.6.75	3	24.6.75	4	-	-	-	-	3	3.50

also been made by Norris (1950, 1952) on African migratory locust and Desert locust and Antoniou and Hunter-Jones (1956) on Eyprepocnemis capitata regarding these aspects.

(vi) Longevity of adults:

Following observations were made from the second set of experiments:

The longevity of adults in both sexes is approximately equal. The life-span of the males on an average is found to be 33.0 ± 1.365 days (range - 26-42 days) while that of female is 33.8 ± 1.957 days (range - 19-42 days) (Table 4).

The longevity of adults mainly depends upon their ability to survive in the extreme conditions of temperature and humidity and secondly on the availability of the food. The difference in the life-span between the males and females is common among the majority of the acridids. In Atractomorpha crenulata the adult male lives for 25 to 36 days and female 36-38 days under laboratory condition (Agrawal, 1955).

Table 4. The longevity of adults of G. transversus Thunb. reared at 32 ± 1°C, and 65 ± 5% R.H., where 12 hours' light altered with 12 hours' darkness, fed on C. dactylon leaves.

Experiment No.	Longevity in days	
	Male	Female
1	32	42
2	36	37
3	42	39
4	33	34
5	26	19
6	30	34
7	30	30
8	32	29
9	36	39
10	33	35
Average	33.0	33.8
± S.E.	± 1.365	± 1.957

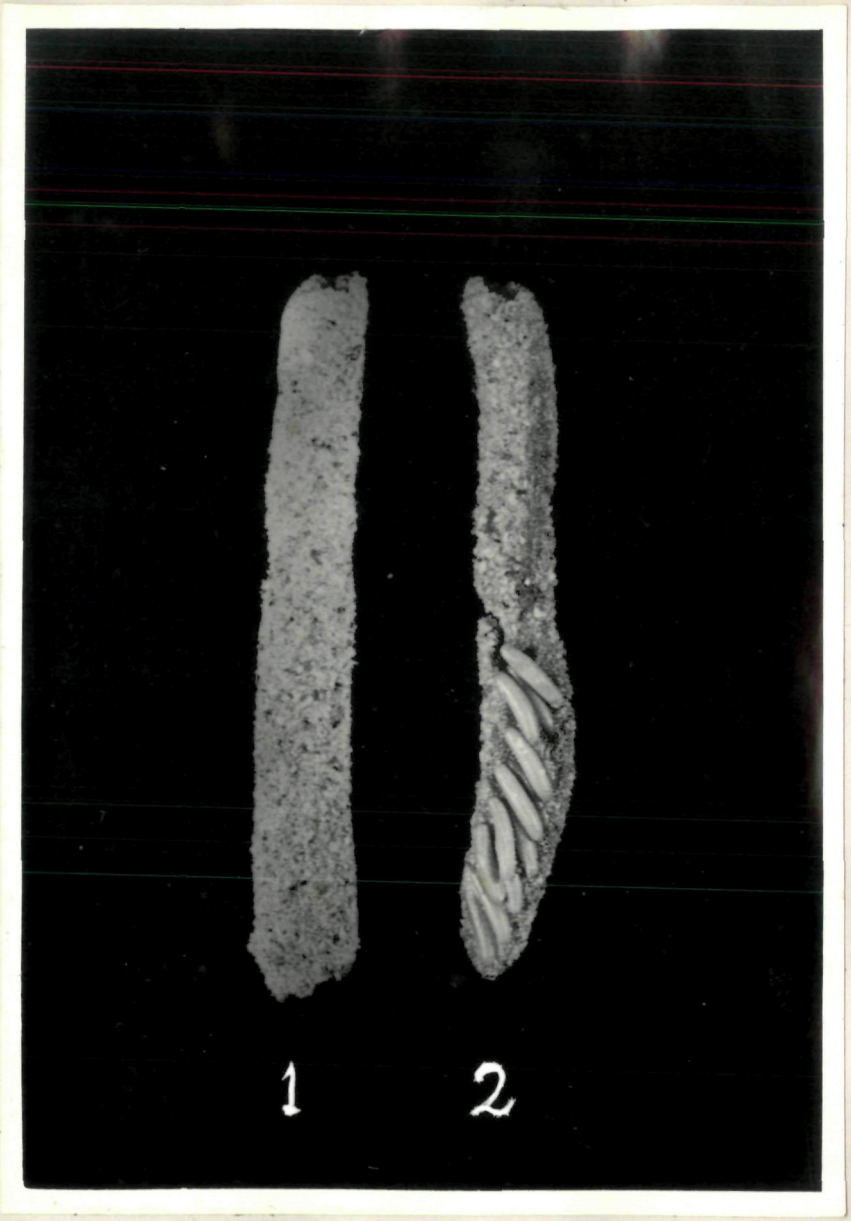
S.E. = Standard Error.

B - EGG-POD

The following observations were made from the second set of experiments:

The female of Gastrimargus transversus Thunb. lays 2-7 egg-pods, averaging 4.1 ± 0.457 egg-pods per female. The average number of eggs per pod is 46.5 ± 3.948 and the number of eggs laid by a single female during life varies from 80-327, averaging 190.8 ± 26.598 (Table 6). It has been observed that there is a decrease in the number of eggs in the successive ovipositions, but in few cases the number of eggs increasesfrom first to third or fourth oviposition and then it declines in successive egg-pods.

The term egg-pod (Plate VII, Fig. 1) is applied to the mass of eggs enclosed in a case formed by hardening of the secretion of the accessory glands exuded at the time of oviposition. The egg-pods are laid 0.2 to 1.0 cm below the surface of the sand and each egg-pod is about 4 cm to 6.5 cm long and 0.5 to 0.7 cm in diameter. They are almost dark-brown in colour and more or less straight and cylindrical in shape. The anterior (apical) end is depressed inwards and the posterior (basal) end forms a convexity. The outerwall of the egg pod is composed of a thin, pink, frothy layer to which sand particles adhere externally and give it a "brownish" or "dirty" appearance. Internally, the secreted frothy material is light pink and spongy. The interior of the pod is one chambered (Plate VII, Fig. 2). The eggs occupy basal portion of the egg-pod while egg-less apical portion remains



Egg-pods of G. transversus Thunb.

Fig. (1) Showing external structure

Fig. (2) Showing interior of the egg-pod.

filled with porous and spongy mass formed of dried secretion. This spongy mass also forms the lamellae between the eggs. The eggs are arranged in a regular pattern at an angle of about 45° to the long axis of the pod, with their posterior or micropylar poles pointing towards the base of the egg-pods. The eggs form 3 or 4 rows in an egg-pod.

(i) Egg:

The freshly laid egg is pale-yellow in colour but later on it changes into light brown. The egg (Plate VIII, Fig. 1) is elongated, cylindrical slightly curved with blunt apex. Freshly laid egg is 5.5 mm in length and 1.2 mm in diameter. The size varies slightly among the eggs of the same egg-pod, but the shape remains the same.

There are two egg-coverings, the chorion and the vitelline membrane. The chorion is thin and densely granulated and the vitelline membrane lies beneath it. In each egg, the micropylar end is distinctly visible being darker than the rest of the egg surface. The operculum is distinctly marked with a dark brown circle.

The eggs gradually increase in size with the embryonic development. Similar increase in size during the embryonic development has also been recorded in various acridids viz., Locusta migratoria (Roonwal, 1936), Melanoplus differentialis (Slifer, 1937) and Schistocerca gregaria (Roonwal, 1953).

Fig. 1. Eggs of G. transversus Thunb.

Fig. 2. (a) Vermiform larva (dorsal view)

(b) Vermiform larva (ventral view)

(ii) Hatching:

The eggs of Gastrimargus transversus Thunb. hatch in 17-20 days and the average incubation period is 18.0 ± 0.311 days (Table 5).

At the time of hatching, the chorion becomes dry and some black spots appear on it near the operculum. It is at these spots that chorion ruptures longitudinally and vermiform larva hatches out. The vermiform larva pushes the lid of the egg-pod and comes to lie on the surface of the sand.

The average percentage of hatching is 73.88 ± 4.982 ranging from 54.34 to 94.36 per cent.

In Gastrimargus africanus Sauss., the incubation period is 18 days at 32°C and 26 days at 28°C (Hunter-Jones and Ward, 1959).

(iii) Fecundity and viability:

The following observations were recorded from the second and fourth sets of experiments:

The average number of egg-pods (Table 6 and 7) per female is 4.1 ± 0.457 (range - 2-7) and 3.8 ± 0.320 in isolated and crowded conditions respectively.

The mean number of eggs per pod in the sample of 91 pods from isolated females is 46.5 ± 3.948 (range - 26-69), and the corresponding number for 85 pods from crowded females is 39.52 ±

Table 5. The incubation period and the fertility and mortality of eggs of *G. transversus* Thunb. at 32 ± 1°C and 65 ± 5% R.H.

Experiment No.	Incubation period (Days)	Percentage of eggs hatched (Fertility)	Percentage of non-viable eggs (Mortality)
1	17	54.34	45.66
2	17	77.41	22.59
3	18	66.66	33.34
4	18	58.62	41.38
5	18	89.47	10.53
6	17	54.54	45.46
7	17	81.78	18.22
8	20	75.34	24.66
9	18	94.36	5.64
10	20	86.32	13.68
Average	18.0	73.884	26.116
± S.E.	± 0.311	± 4.982	± 4.636

S.E. = Standard Error.

Table 6. The fecundity of females of G. transversus Thunb. reared in isolation at 32 ± 1°C and 65 ± 5% R.H., where 12 hours' light altered with 12 hours' darkness fed on C. dactylon leaves.

Experiment No.	Total no. of egg-pods/ female	Number of eggs at each oviposition							Total no. of eggs laid/ female
		I	II	III	IV	V	VI	VII	
1	4	64	62	59	56	-	-	-	241
2	5	69	52	42	55	56	-	-	274
3	3	48	44	34	-	-	-	-	126
4	5	35	26	30	62	50	-	-	203
5	3	39	33	30	-	-	-	-	102
6	-	-	-	-	-	-	-	-	-
7	2	46	34	-	-	-	-	-	80
8	-	-	-	-	-	-	-	-	-
9	4	55	45	48	50	-	-	-	198
10	3	47	27	35	-	-	-	-	109
11	5	65	54	62	52	32	-	-	265
12	7	61	47	44	46	41	44	44	327
13	3	50	44	34	-	-	-	-	128
14	5	67	46	42	42	40	-	-	237
15	3	62	52	53	-	-	-	-	167
16	5	40	33	30	48	45	-	-	196
17	4	34	37	30	34	-	-	-	125
18	2	50	34	-	-	-	-	-	84
19	3	51	44	44	-	-	-	-	139
20	4	50	26	35	52	-	-	-	163
21	7	49	47	45	44	46	46	44	321
22	5	61	59	53	59	50	-	-	282
23	-	-	-	-	-	-	-	-	-
24	4	61	45	53	67	-	-	-	226
25	5	60	48	49	47	45	-	-	249
Average	4.1	52.9	42.2	42.6	51.0	45.0	45.0	44.0	190.8
± S.E.	±0.457	± 3.342	±3.387	±3.202	±2.709	±2.185	±0.414	±0.000	±26.598

S.E. = Standard Error.

Table 7. Showing the effect of density on fecundity of females of G. transversus Thunb. reared at 32 ± 1°C and 65 ± 5% R.H., where 12 hours' light altered with 12 hours' darkness, fed on C. dactylon leaves.

Rearing density	Number of females taken	Number of females died	Total no. of egg-pod laid	Average no. of egg-pods/ female	Total no. of eggs laid	Average no. of eggs/ egg-pod	Average fecundity
Isolation	25	3	91	4.1 ±0.457	4242	46.5 ±3.948	190.65 ±26.598
Crowding	25	3	84	3.8 ±0.320	3320	39.5 ±3.102	150.17

Table 7a. Showing the effect of density on viability and non-viability of egg-pods and eggs of G. transversus Thunb. reared at 32 ± 1°C and 65 ± 5% R.H., where 12 hours' light altered with 12 hours' darkness, fed on C. dactylon leaves.

Rearing density	No. of egg-pods placed for incubation	No. of viable egg-pods	No. of non-viable egg-pods	Percentage of viable egg-pods	Percentage of non-viable egg-pods	Percentage of eggs hatched (Fertility) ± S.E.	Percentage of non-viable eggs (Mortality) ± S.E.
Isolation	60	48	12	80	20	73.884 ± 4.982	26.116 ± 4.636
Crowding	84	69	15	82	18	83.4 ± 3.880	16.5 ± 3.875

S.E. = STANDARD ERROR.

3.102 (range - 28-56) (Table 7). The average fecundity (mean number of eggs per pod multiplied by mean number of pods) is 46.5 x 4.10 = 190.65 eggs for isolated female and 39.52 x 3.8 = 150.176 eggs for crowded female (Table 7).

Twenty per cent of egg-pods laid by isolated females did not hatch at all and from the viable egg-pods 26.116% (Table 5) of the eggs did not hatch. The corresponding figures for the crowding adults were 18% and 16.5% respectively (Table 7a). It is possible to obtain four generations in a year in the laboratory.

C - VERMIFORM LARVA

Following observations were obtained from the second set of experiments:

The vermiform larva (Plate VIII, Fig. 2) remains enclosed in a thick, transparent cuticular membrane. In this position its head bends downwards, antennae and legs lie close to the body giving a sac like appearance. The larvae make their way up through the dry froth by wriggling movement of their abdomen and all of them emerge forming a cluster over the mouth of the egg-pod. The emergence of all the larvae from a single egg-pod takes about 10-15 minutes. On reaching the surface of the sand, the cuticle of the larva bursts by vigorous pulsations of the cervical ampullae and wriggling movements of the body assisted by the legs. The larva becomes free and gets out of the first cast skin. The

shed cuticle shrivels up into a whitish lump and the ground near the exit is strewn with such lumps. This first shedding of cuticle is called "intermediate moult". The process of intermediate moult is completed within 2-4 minutes.

D - (i) Hopper instars:

The following observations were made from the third set of experiments:

The newly hatched hoppers of G. transversus Thunb. are negatively geotropic as they move upwards and ascend the plants and walls of glass jars. They are very active and start feeding just after their emergence. The number of hoppers hatched varies from 12 to 62 hoppers per egg-pod.

A variation has been recorded in the number of nymphal instars among the isolated hoppers of G. transversus Thunb. During the present experiments, the individuals were found having 4-7 hopper instars (the intermediate moult is not included in this count). Among the isolated males, fed on C. dactylon leaves, 90 per cent of them were found to have five instars and 10 per cent with six instars, but when reared on maize 12 per cent of them were found to have four instars. Among the isolated females, about 80 per cent of them had six instars and 20 per cent had seven instars. Similar variation in hopper instars has also been recorded in G. africanus Sauss. by Hunter-Jones and Ward (1959).

but there it varies from 4-6 instars only.

The average duration of isolated male hoppers (Table 8), was 8.6 ± 0.163 days, 5.8 ± 0.328 days, 4.7 ± 0.260 days, 6.3 ± 0.213 days and 9.10 ± 0.457 days for 1st, 2nd, 3rd, 4th and 5th instars respectively having five instars and 8.80 ± 0.199 days, 4.8 ± 0.249 days, 4.4 ± 0.232 days, 5.3 ± 0.213 days, 7.0 ± 0.258 days and 8.0 ± 0.333 days for 1st, 2nd, 3rd, 4th, 5th and 6th instars isolated males respectively having six instars. The average total duration of nymphal period was 34.6 ± 0.498 days and 38.4 ± 0.400 days respectively for five and six instar isolated males. The daily rate of development was 2.88 per cent and 2.60 per cent for five and six instar isolated male hoppers respectively (Table 10). In cases where there was only four instars in isolated males, the average hopper duration was 6.3 ± 0.260 days, 8.0 ± 0.258 days, 10.6 ± 0.370 days and 10.1 ± 0.433 days for 1st, 2nd, 3rd and 4th instars respectively. The total average hopper duration and daily rate of development for the male hoppers were 35.0 ± 0.421 days and 2.85 per cent respectively.

Similarly, the average duration of isolated female hoppers (Table 9) was 8.6 ± 0.163 days, 5.7 ± 0.260 days, 4.7 ± 0.300 days, 5.4 ± 0.221 days, 7.6 ± 0.353 days and 10.6 ± 0.305 days for 1st, 2nd, 3rd, 4th, 5th and 6th instars respectively and 6.4 ± 0.397 days, 7.1 ± 0.433 days, 6.0 ± 0.211 days, 5.5 ± 0.166 days, 5.9 ± 0.275 days, 5.8 ± 0.249 days and 12.9 ± 0.736 days for 1st, 2nd, 3rd, 4th, 5th, 6th and 7th instars respectively. The average total

Duration (in days) of different hoppers of G. transversus Thunb. (Male), reared at 32 ± 1°C and 65 ± 5% R.H., 12 hours' light altered with 12 hours' darkness.

(Based on 10 experiments, one hopper in each replicate)

tar		II instar			III instar			IV instar			V instar		VI instar	Total hopper duration		
B	C	A	B	C	A	B	C	A	B	C	B	C	C	A	B	C
9	9	7	5	4	11	4	6	10	6	5	10	6	10	35	34	40
8	8	8	4	6	9	4	4	12	7	6	8	7	7	35	32	39
9	9	9	5	5	10	5	4	10	6	4	9	8	8	34	34	38
9	9	8	6	5	12	6	4	10	6	5	7	7	8	37	34	38
8	9	7	7	5	11	4	4	11	6	6	11	7	6	36	36	37
9	8	9	6	6	10	5	5	10	5	6	11	7	8	35	36	40
8	9	8	7	4	12	6	5	8	6	6	7	8	8	35	34	40
8	8	8	5	4	9	4	4	12	7	5	9	8	9	35	33	38
9	9	7	7	5	10	5	4	8	7	5	9	6	8	32	37	37
9	10	9	6	4	12	4	4	10	7	5	10	6	8	36	36	37
8.6	8.8	8.0	5.8	4.8	10.6	4.7	4.4	10.1	6.3	5.3	9.1	7.0	8.0	35.0	34.6	38.4
.163	±0.199	±0.258	±0.328	±0.249	±0.370	±0.260	±0.232	±0.433	±0.213	±0.213	±0.457	±0.258	±0.333	±0.421	±0.498	±0.400

Group A = Hoppers having 4 instars to reach adult stage

9. Duration (in days) of different hoppers of G. transversus Thunb. (Female), reared at 32 ± 1°C and 65 ± 5% R.H., 12 hours' light altered with 12 hours' darkness.

(Based on 10 experiments, one hopper in each replicate)

instar	II instar		III instar		IV instar		V instar		VI instar		VII instar	Total hopper duration	
B	A	B	A	B	A	B	A	B	A	B	B	A	B
5	5	6	5	7	6	5	6	7	12	6	17	42	53
9	7	7	5	6	6	6	9	5	11	7	11	37	51
7	6	5	6	6	4	5	8	6	10	5	12	43	46
5	4	10	5	5	5	6	9	5	12	5	15	43	46
6	6	7	3	6	6	5	8	6	9	6	10	40	46
6	6	7	6	7	5	6	8	7	10	6	13	44	52
7	6	8	4	6	5	6	6	7	10	7	12	40	53
6	5	8	4	6	6	5	8	6	11	6	10	42	47
6	6	6	4	5	5	6	8	5	10	5	15	42	48
7	6	7	5	6	6	5	6	5	11	5	14	43	39
.6	6.4	5.7	7.1	4.7	6.0	5.4	5.5	7.6	5.9	10.6	5.8	12.9	41.6	48.1
163	±0.397	±0.260	±0.433	±0.300	±0.211	±0.221	±0.166	±0.353	±0.275	±0.305	±0.249	±0.736	±0.565	±1.370

Group A = Hoppers having 6 instars to reach adult stage

Table 10. Average duration and daily rate of development of different hopper instars of G. transversus Thunb. reared at 32 ± 1°C and 65 ± 5% R.H, where 12 hours' light altered with 12 hours' darkness, based on 10 experiments.

Sex	No. of instars	Average duration of instars in days ± S.E.							Average total duration (days)	Daily rate of development (percentage)
		I	II	III	IV	V	VI	VII		
Male	4	6.3 ±0.260	8.0 ±0.258	10.6 ±0.370	10.1 ±0.433	-	-	-	35.0 ± 0.421	2.85
	5	8.6 ±0.163	5.8 ±0.328	4.7 ±0.260	6.3 ±0.213	9.1 ±0.457	-	-	34.6 ± 0.498	2.88
	6	8.8 ±0.199	4.8 ±0.249	4.4 ±0.232	5.3 ±0.213	7.0 ±0.258	8.0 ±0.333	-	38.4 ± 0.400	2.60
Female	6	8.6 ±0.163	5.7 ±0.260	4.7 ±0.300	5.4 ±0.221	7.6 ±0.353	10.6 ±0.305	-	41.6 ± 0.565	2.40
	7	6.4 ±0.397	7.1 ±0.433	6.0 ±0.211	5.50 ±0.166	5.9 ±0.275	5.8 ±0.249	12.9 ±0.736	48.1 ± 1.370	2.07

S.E. = Standard Error.

duration of hopper period was 41.6 ± 0.565 days and 48.1 ± 1.370 days for six and seven instar females respectively. The daily rate of development was 2.40 per cent and 2.07 per cent for six and seven instar isolated females respectively (Table 10).

The colouration and its pattern have also been found to vary from one instar to another and in the same instars as well. Similar observations have also been made by Hunter-Jones and Ward (1959) in G. africanus Sauss.

(ii) Description of hopper instars:

The following observations were made from the first set of experiments:

First instar hopper (Plate IX, Figs. A1, B1, C1, Plate X, Figs. A1, B1).- The freshly hatched first instar hopper is pale yellowish in colour, but later on dark brown stripes and spots make their appearance on the whole body. It measures 5 mm in length and 1.7 mm in width across the pronotum.

At the time of hatching, the head is larger in comparison with the body, but later on abdomen increases in size; head is of orthognathus type, 1 mm in length and 1.4 mm in width and is conical in shape projecting anteriorly between the compound eyes and forms a triangular structure known as "fastigium"; eyes elliptical in shape with horizontal brown and white stripes in middle. Antennae light brown or reddish, filiform somewhat

clavate distally, 13-segmented and 1.8 mm in length. Mandibles light brown and unsclerotized; apices of mandibular teeth strongly acute (Plate XI, Figs. AI, BI, CI; Plate XII, Figs. AI, BI).

Thorax measures 1.6 mm in length and 1.7 mm in width across the pronotum; pronotum with well developed median carina, slightly projecting anteriorly covering posterior part of head, and angulated behind covering part of mesonotum. Meso- and metathorax with slight extensions at their postero-lateral sides. Hind legs stout and larger than fore and midlegs; hind femur 3.1 mm in length and 0.9 mm in width, hind bibiae with tibial spines.

Abdomen cylindrical 2.5 mm in length, 11-segmented, about as long as head and thorax combined; tympanal organ absent; cerci small; sexes may be differentiated by the shape of notch present on posterior margin of subgenital plates. In case of males it is U-shaped whereas in females it is V-shaped.

Second instar hopper (Plate IX, Figs. A2, B2, C2; Plate X, Figs. A2, B2).- Resembles first instar hopper except in the following characters:

Body light brownish with dark brown spots over the whole body, measuring 6-7 mm in length and 2 mm in width across the pronotum; Head 1.2 mm in length and 1.6 mm in width; antennae 15-16 segmented and 2.2 mm in length; apices of mandibular teeth rounded (PlateXI, Figs. AII, BII, CII; Plate XII, Figs. AII, BII). Thorax measures 1.9-2 mm in length and 2 mm in width across the pronotum;

meso- and metanotum with thinner extensions pointing downward and are slightly infuscated; hind femur much stout and of 3.8 mm in length and 1 mm in width. Abdomen 2.9-3 mm in length; external genital organs undergo further development.

Third instar hopper (Plate IX, Figs. A3, B3, C3; Plate X, Figs. A3, B3).- Resembles second instar hopper except in the following characters:

Colour variable light brown, dark brown, muddy, metallic (copper colour) or green. In some cases body brownish with green patches on the head and thorax. Body measures 9.5-10 mm in length and 2.8 mm in width across the pronotum in females and 8.5-9 mm in length and 2.6 mm in width across the pronotum in males. Head 2.6 mm in length and 2.6 mm in width; antennae 17-segmented and 3.5 mm in length; apices of mandibular teeth strongly acute (Plate XI, Figs. AIII, BIII, CIII; Plate XII, Figs. AIII, BIII). Thorax measures 2.5 mm in length and 2.6-2.8 mm in width across the pronotum; meso- and metanotum with well developed wing pads pointing downward and with indistinct veins; hind femur much stout and 5-5.5 mm in length and 1.4 mm in width. Abdomen measures 4.0-4.5 mm in length; tympanal organ developed on the first abdominal segment; male sub-genital plate becomes V-shaped and protrudes a little beyond the last abdominal segment, female genital valves become more distinct.

Fourth instar hopper (Plate IX, Figs. A4, B4, C4; Plate X, Figs. A4, B4).- Resembles third instar hopper except in the

following characters:

Body measures 16-18 mm in length and 3.5 mm in width across the pronotum in females and 12-16 mm in length and 3.0 mm in width across the pronotum in males. In both sexes head measures 2.8-3.0 mm in length and 2.7-2.8 mm in width; antennae 20 to 22-segmented and 6 mm in length; apices of the mandibular teeth somewhat rounded (Plate XI, Figs. AIV, BIV, CIV; Plate XII, Figs. AIV, BIV). Thorax 6-6.5 mm in length and 3.0-3.5 mm in width across the pronotum in females and 4.0-6.0 mm in length and 2.8-3.0 mm in width across the pronotum in males. There is a marked variation in the development of the wing-pads which is closely associated with the number of instars (4-7) to reach the adult. In cases having 6-7 instars to reach adult, wing-pads directing downward with indistinct veins; in cases having five instar to reach adult, wing pads well developed, turned upward and extending upto first abdominal segment with somewhat distinct veins, but in cases having four instar to reach adult the wing-pads much developed, turned upward and extending upto 3rd abdominal segment with distinct veins which are radially disposed; hind femur measuring 9.0 mm and 2.5 mm in width in females and 7.0 mm in length and 2.1 mm in width in males. In both sexes genitalia undergo further development and much extend beyond the apex of supra anal plate.

Fifth instar hopper (Plate IX, Figs. B5, C5; Plate X; Figs. A5, B5).- Some of the male hoppers directly attain the adult stage after the fourth instar.

The fifth instar hoppers resemble with fourth instar hoppers except in the following characters:

Body measures 20-23 mm in length and 3.8 mm in width across the pronotum in females and 13-19 mm in length and 3.2 mm in width across the pronotum in males. Head is 3.5 mm in length and 3.5 mm in width in female and 3.0-3.5 mm in length and 3.0 mm in width in males; antennae 24 to 25-segmented, 8-9 mm in length in females and 6 mm in length in males; apices of mandibular teeth truncate (Plate XI, Figs. BV, CV; Plate XII, Figs. AV, BV). In this instar also there is marked variation in the development of wing-pads. In cases having 6-7 instar to reach adult, the wing pad directing upwards extending upto first abdominal segment and with distinct veins; in cases having five instars to reach adult, the wing pads turned upward and extend upto third abdominal segment with distinct veins which are radially disposed; hind femur measuring 11 mm in length and 3.2 mm in width in females, 9.2-11.2 mm in length and 2.5-3 mm in width in case of males. The external genitalia in both sexes undergo further development.

Sixth instar hopper (Plate IX, Figs. C6; Plate X; Figs. A6, B6).- Most of the male hoppers directly attain the adult stage after fifth instar.

Sixth instar hoppers resemble with fifth instar hoppers except in the following characters:

Body colour being darker and is variable from individual to individual in both sexes. In case of females having six instars

to reach adult body measures 29-30 mm in length and 5 mm in width; wing pads extending upto 3rd abdominal segment and with distinct veins which are radially disposed; hind femur 14-16 mm in length and 4.0 mm in width. But in case of females having seven instars to reach adult body measures 25.5 mm in length and 4.5 mm in width across the pronotum; wing-pads extending upto second abdominal segment with distinct veins; hind femur measuring 13-14 mm in length and 4.5 mm in width; antennae in both cases 26-27 segmented. Ventral valves and ovipositor valves of the female genitalia curved downward and upward respectively. In case of males, body measures 21 mm in length and 3.2 mm in width across the pronotum; wing-pads extending upto third abdominal segment with radially disposed veins; antennae 26 to 27-segmented; hind femur 9.5 mm in length and 3.1 mm in width; external genitalia undergo further development.

In both sexes mandibles with truncate apices (Plate XI, Fig. CVI; Plate XII, Figs. AVI, BVI).

Seventh instar hopper (Plate X, Fig. B7).- Most of the female hoppers attain the adult stage after the sixth instar.

Seventh instar hoppers resemble with sixth instar hoppers except in the following characters:

Body dark brown or black, 29-31 mm in length and 6.0 mm in width across the pronotum; antennae 27-28 segmented and 9-10 mm in length; mandibles with broadly truncated apices (Plate XII, Fig. BVII). Wing-pads turn upward and extend

EXPLANATION OF PLATE IX

Group A - Male hoppers having 4 instars to reach adult stage.

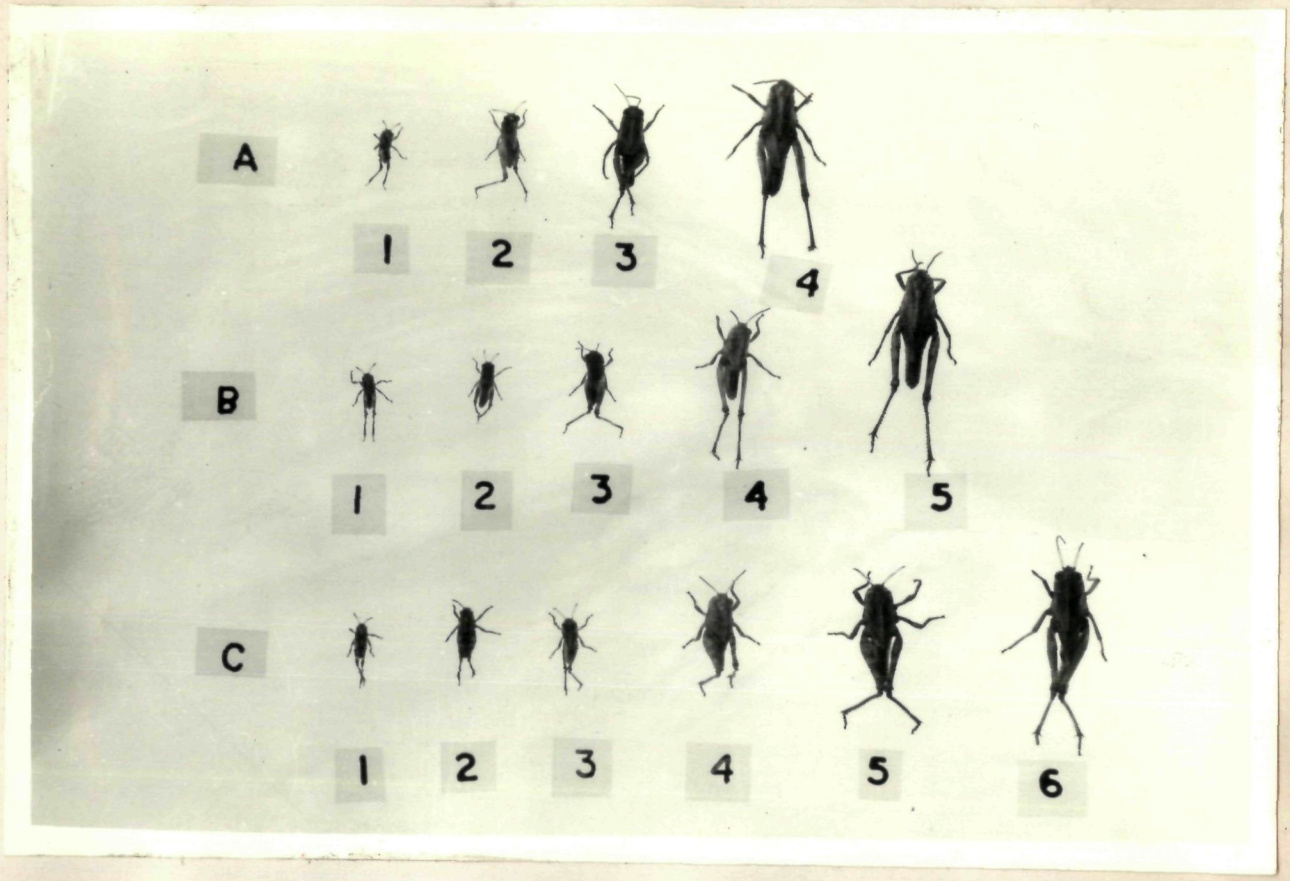
1. First instar hopper.
2. Second instar hopper.
3. Third instar hopper.
4. Fourth instar hopper.

Group B - Male hoppers having 5 instars to reach adult stage.

1. First instar hopper.
2. Second instar hopper.
3. Third instar hopper.
4. Fourth instar hopper.
5. Fifth instar hopper

Group C - Male hoppers having 6 instars to reach adult stage.

1. First instar hopper.
2. Second instar hopper.
3. Third instar hopper.
4. Fourth instar hopper.
5. Fifth instar hopper.
6. Sixth instar hopper.



Different hopper instars of G. transversus Thunb. (MALE)

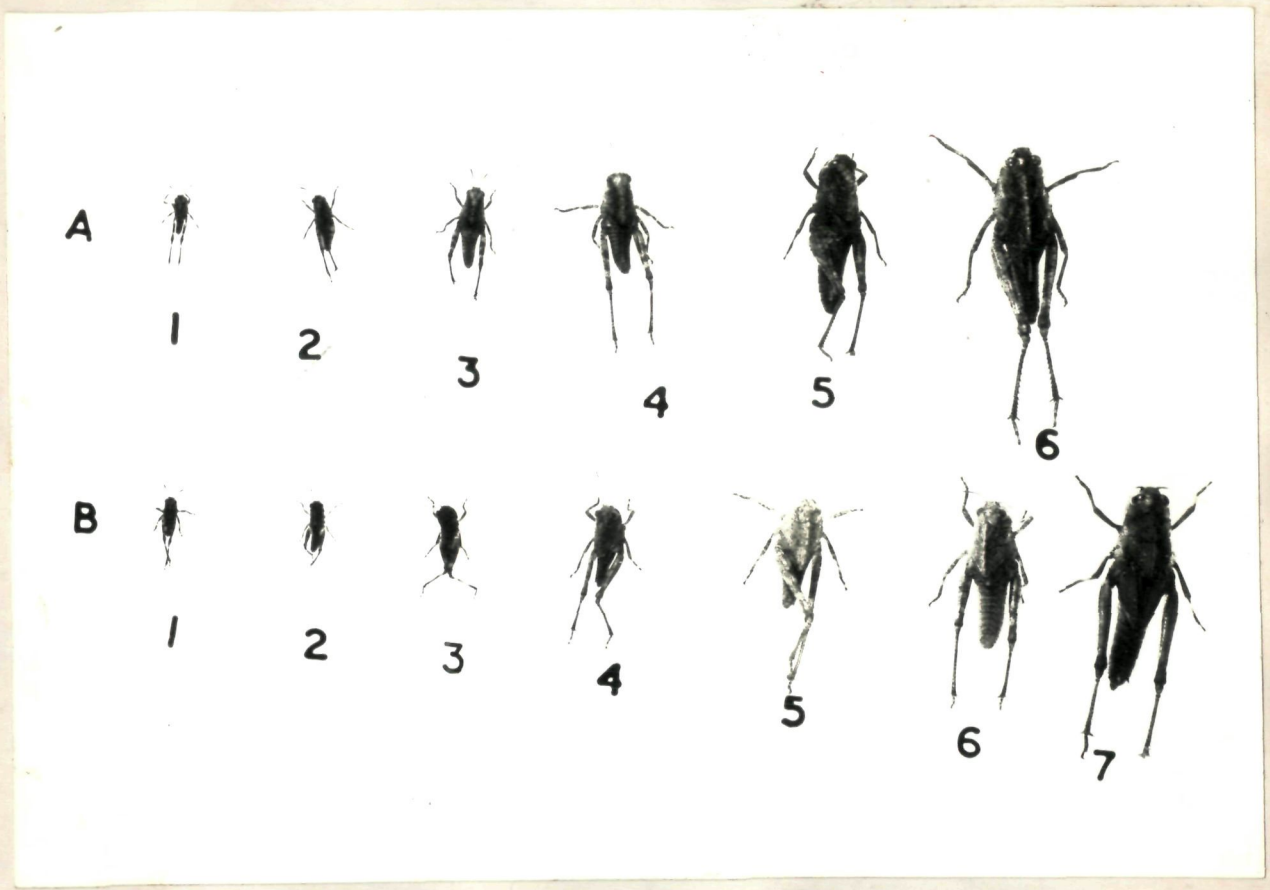
EXPLANATION OF PLATE X

Group A - Female hoppers having 6 instars to reach adult stage.

1. First instar hopper.
2. Second instar hopper.
3. Third instar hopper.
4. Fourth instar hopper.
5. Fifth instar hopper.
6. Sixth instar hopper.

Group B - Female hoppers having 7 instars to reach adult stage.

1. First instar hopper.
2. Second instar hopper.
3. Third instar hopper.
4. Fourth instar hopper.
5. Fifth instar hopper.
6. Sixth instar hopper.
7. Seventh instar hopper.



Different hopper instars of G. transversus Thunb. (FEMALE)

EXPLANATION OF PLATE XI

Group A - Mandibles of male instar hoppers having 4 instars to reach adult stage.

I Mandible of first instar hopper.

II Mandible of second instar hopper.

III Mandible of third instar hopper.

IV Mandible of fourth instar hopper

Group B - Mandibles of male instar hoppers having 5 instars to reach adult stage.

I Mandible of first instar hopper.

II Mandible of second instar hopper.

III Mandible of third instar hopper.

IV Mandible of fourth instar hopper.

V Mandible of fifth instar hopper.

Group C - Mandibles of male instar hoppers having 6 instars to reach adult stage.

I Mandible of first instar hopper.

II Mandible of second instar hopper.

III Mandible of third instar hopper.

IV Mandible of fourth instar hopper.

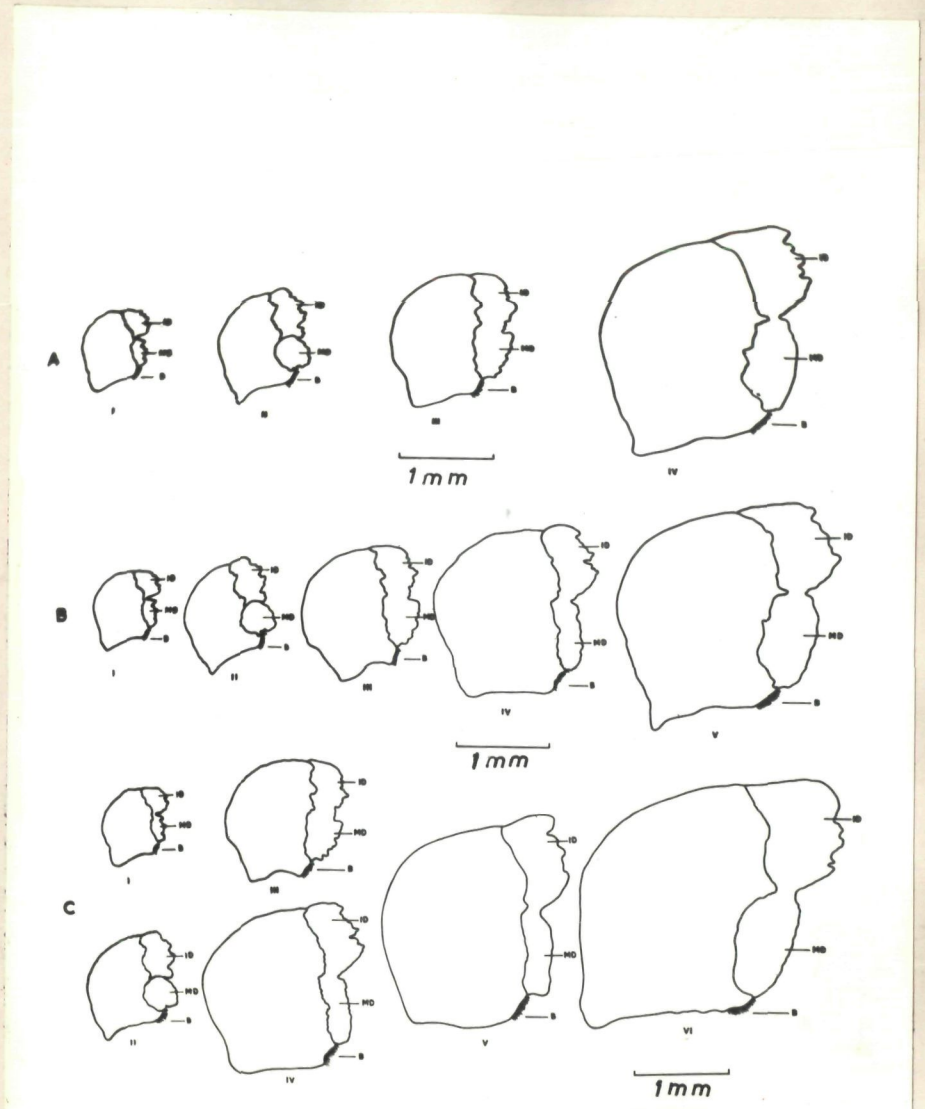
V Mandible of fifth instar hopper.

VI Mandible of sixth instar hopper

Abbreviations - MD = Molar dents

ID = Incisor dents

B = Brush (brustia)



MANDIBLES OF VARIOUS STAGES OF G. TRANSVERSUS THUNB. MALE

Mandibles of various hopper stages of G. transversus Thunb. (MALE)

EXPLANATION OF PLATE XII

Group A - Mandibles of female instar hoppers having 6 instars to reach adult stage.

I Mandible of first instar hopper.

II Mandible of second instar hopper.

III Mandible of third instar hopper.

IV Mandible of fourth instar hopper.

V Mandible of fifth instar hopper.

VI Mandible of sixth instar hopper.

Group B - Mandibles of female instar hoppers having 7 instars to reach adult stage.

I Mandible of first instar hopper.

II Mandible of second instar hopper.

III Mandible of third instar hopper.

IV Mandible of fourth instar hopper.

V Mandible of fifth instar hopper.

VI Mandible of sixth instar hopper.

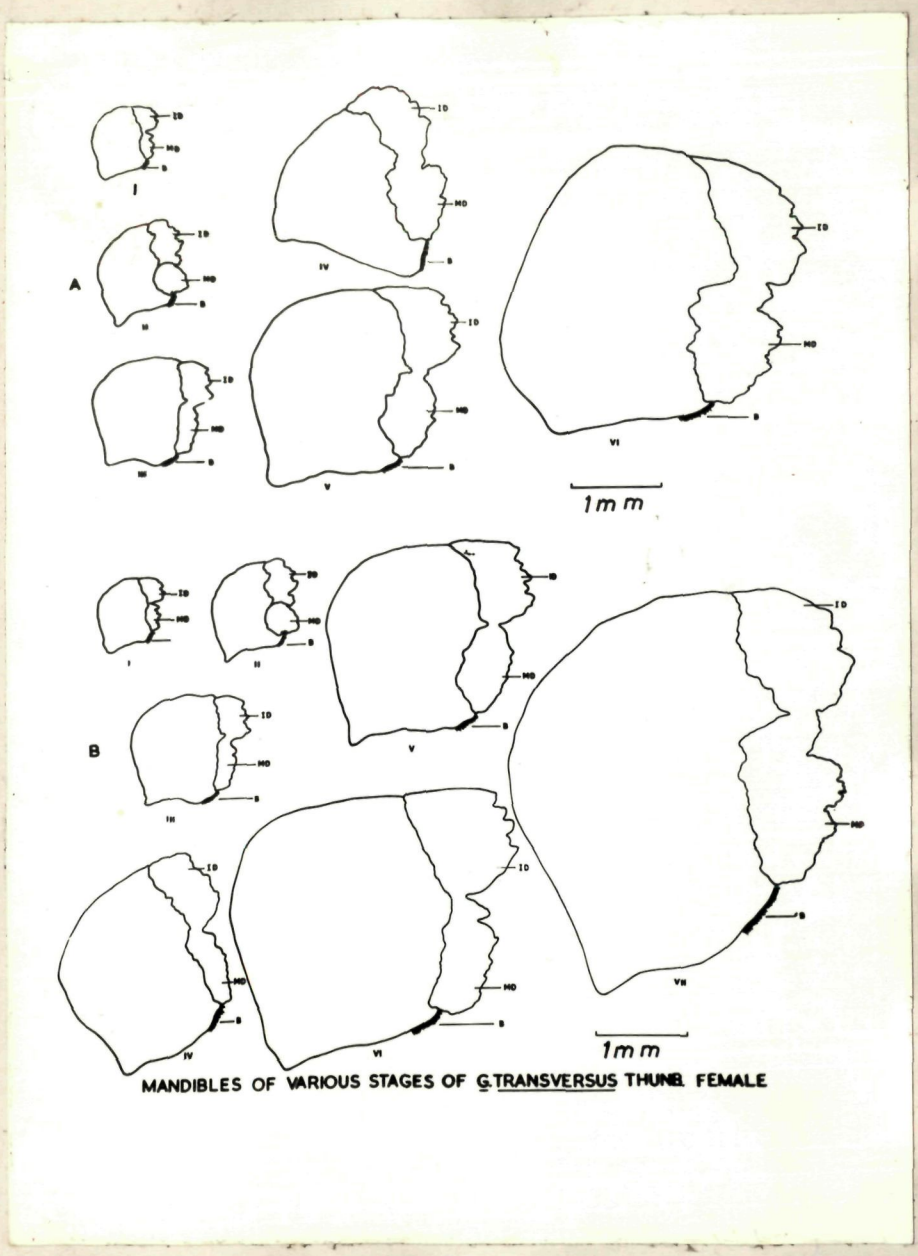
VII Mandible of seventh instar hopper.

Abbreviations - MD = Molar dents

ID = Incisor dents

B = Brush (brustia)

PLATE XII



MANDIBLES OF VARIOUS STAGES OF G.TRANSVERSUS THUNB. FEMALE

Mandibles of various hopper stages of G. transversus Thunb. (FEMALE)

posteriorly upto 3rd abdominal segment with radially disposed veins. The external genitalia get fully developed.

The hoppers just before moulting stop feeding and rest on the twig. After sometime they begin the rhythmic contraction and expansion of the anterior region of the body. Its head is moved forward and backwards. The pronotum moves upwards and downwards by contraction of cervical ampulla resulting the rupture of cuticle along the mid-dorsal line above the pronotum. This slit further increases from the fastigium upto the wing-pads. Gradually the insect creeps out the old cuticle. The old cuticle is discarded as the adult emerges. The newly emerged adult is called as "Fledgeling". During the whole process of moulting the hopper breathes hard and keeps on expanding and contracting its body. Just after the moult, the fore-wings are expanded partially and hind-wings are folded like a fan. After 20-25 minutes the fore-wings get fully expanded. The hind-wings are hyaline and are also stretched after emergence and then slowly folded back to the same position. The insect now rests for a while and then starts feeding.

ife-cycle of G. transversus Thunb. reared at 32 ± 1°C and 65 ± 5% R.H., where 12 hours' light
ltered with 12 hours' darkness, fed on C. dactylon leaves.

(Date based on 10 replicates)

ng on	Length of period in days: Pre-copulation	Pre-oviposition	Oviposition	Post-oviposition	Eclosion to death	Total life span	No. of egg-pods laid	No. of eggs in successive egg-pods
	6	-	-	-	32	71	-	-
	9	6	23	4	42	88	7	61,46,44,46,41,45,44 = 327
	7	-	-	-	36	82	-	-
	10	7	17	3	37	85	5	69,52,42,55,56 = 274
	8	-	-	-	42	83	-	-
	10	10	18	1	39	88	3	48,44,34 = 126
	7	-	-	-	33	75	-	-
	9	5	17	3	34	84	4	64,62,59,56 = 239
	6	-	-	-	26	66	-	-
	7	5	6	1	19	70	2	46,34 = 80
	7	-	-	-	30	70	-	-
	9	6	16	3	34	78	3	39,33,30 = 102
	8	-	-	-	30	69	-	-
	9	5	15	1	30	79	5	35,26,30,61,50 = 202
	6	-	-	-	32	74	-	-
	8	5	15	1	29	80	3	47,27,35 = 109
	7	-	-	-	36	80	-	-
	7	8	22	2	39	89	5	65,54,62,52,32 = 265
	6	-	-	-	33	75	-	-
	9	5	20	1	35	84	4	54,45,48,36 = 184
6	6-8	-	-	-	26-42	66-83	-	Average of I egg-laying = 52.9

3. DISCUSSION

The adults of Gastrimargus transversus Thunb. are gregarious and assemble in masses on the grasses, bushes and tree tops upto a height of 15-20 feet to bask in the sun. They are photopositive and usually get disturbed on falling of shadows. Similar behaviour has been observed in Aularches punctatus by Katiyar (1955) and in various acridid pests by various authors. The gregarious nature has also been recorded by Hunter-Jones and Ward (1959) in its allied species, G. africanus Sauss. When adults or late hopper instars are caught, they emit a blackish offensive secretion with pungent smell. Katiyar (1955) also recorded similar secretion in A. punctatus, but Hingston (1927) in A. miliaris found it to be as clear as water but sometimes turbid or faint yellow.

The process of copulation does not start immediately after emergence. Both males and females do not reach maturity simultaneously. The precopulation period varies from 6-8 days (average - 6.8 ± 0.249 days) in males and 7-10 days (average - 8.7 ± 0.338 days) in females. Among other acridids, the males and females reach maturity at the same time e.g., in A. punctatus (Katiyar, 1955) the precopulation period was noticed as 12 days. In other cases the males take time to mature after their emergence, while females are ready for copulation after their emergence. Pruthi and Nigam (1939) also observed the same in Poecilocerus pictus and Iqbal and

Aziz (1973) in Spathosternum parasiniferum Walk. The process of copulation is very similar what has been demonstrated in large number of other acridoids e.g., Anacridium aegyptium (Fedorov, 1927), Schistocerca gregaria (Uvarov, 1966), Locusta migratoria (Boldyrev, 1929) and Melanoplus differentialis (Kyl, 1938). During copulation, the adults of G. transversus Thunb. show considerable intraspecific variation in the mode of copulation. The copulating pairs were found in dorso-lateral posture or hanging posture or intermediate posture between dorso-lateral and hanging postures. Katiyar (1956b) in G. transversus Thunb. and Oedaleus abruptus, has also recorded intraspecific variation in the mode of copulation which varies from dorso-lateral (Mode II) to the hanging type (Mode III). Katiyar (1956b) attributed this intraspecific variation during copulation for the species where the sexes considerably differ in size as adults. According to Katiyar (1956b), the sex ratio among G. transversus Thunb. varies from 1.42-1.61. Female G. transversus Thunb. with a male in copulo may continue to feed, crawl and even hop. Similar observations have been recorded in Schistocerca gregaria (Popov, 1958) and Spathosternum parasiniferum Walk. (Iqbal and Aziz, 1973). Some species e.g., Spanacris (Hebard, 1937) may even fly with the male. The copulation is repeated several times. The copulation is not necessary for successive ovipositions. The first copulation may be sufficient to fertilize the eggs in all the succeeding ovipositions. Similar observations have also been made in Schistocerca gregaria (Norris, 1954).

Female G. transversus Thunb. usually deposits its eggs in the moist sand, but sometimes egg-clutch has also been recorded on the leaves of host plant. During oviposition, the female of G. transversus Thunb. bores holes, 4.0 to 6.5 cm deep, though the abdomen is only 2.0 to 2.2 cm long in normal condition. It can be stretched to reach the depth of egg-chamber with the help of inter-segmental membranes. The abdomens of females are also extended in other acridoids like in Anacridium aegyptium from 3.5 to 9-10 cm (Fedorov, 1927), Acrida pellucida from 4.5 to 15-17 cm (Hafez and Ibrahim, 1958), Aularches punctatus from 2.6 to 7.7 cm (Katiyar, 1955) and Atractomorpha granulata from 8 to 10 cm (Agrawal, 1955). From above it may be concluded that the depth of the holes for the oviposition may vary from species and it depends upon the extension of the abdomen of the species concerned.

The average number of egg-pods per female of G. transversus Thunb. is 4.1 ± 0.457 and 3.8 ± 0.320 in isolated and crowded conditions. But in G. africanus Sauss. Hunter-Jones and Ward (1959) recorded 9.9 and 6.6 pods per female under isolated and crowded conditions respectively. The small number of pods produced by crowded female was probably associated with their pre-mature death (Hunter-Jones and Ward, 1959). In G. transversus Thunb. crowding does not affect the sexual maturation period and egg-laying rate of the female. The sexual maturation period in isolated and crowded conditions was found approximately similar, being

15.5 ± 0.507 days and 15.0 ± 826 days respectively. The egg-laying rate in isolated and crowded conditions also remained the same i.e., 2 egg-pods per female per week. Hunter-Jones and Ward (1959) recorded similar observations in G. africanus Sauss. where the pre-maturation period in isolated and crowded conditions was 19.2 days and egg-laying rate was 2 egg-pods per female per week. Norris (1950-1952) in the African migratory locust and Desert locust recorded the duration of the first oviposition for similarly isolated females to be 11 and 38 days respectively and for crowded females, were 18-23 and 21-29 days. For isolated and crowded females, the interval between the successive egg-laying was 3 and 7 days respectively.

However, crowding affects the fecundity and fertility of eggs of G. transversus Thunb. The average number of eggs per pods is 46.5 ± 3.948 and 39.52 ± 3.102 in isolated and crowded conditions respectively. Thus the average fecundity for isolated adult is higher (190.65 eggs) than the crowded adults (150.176 eggs). Similar observations have been recorded by Hunter-Jones and Ward (1959) in G. africanus Sauss, where the average number of eggs per pod was 57.1 and 32.7 for isolated and crowded adults, giving an average fecundity 565.3 eggs for isolated females and 347.8 for crowded females. The highest fecundity among acridids has been recorded by Antoniou and Hunter-Jones (1956) in Eyprepocnemis capitata Mill. which is 1008 eggs for isolated female and 1030 eggs for crowded female. Thus in G. transversus Thunb. the average fecundity , unlike that of E. capitata, for isolated

adult is higher than crowded adult.

20 per cent of egg-pods laid by isolated females were totally sterile and among the fertile egg-pods 26.116% of eggs do not hatch. The corresponding figures for the crowding adults were 18% and 16.5% respectively. Antoniou and Hunter-Jone (1956) have recorded in E. capitata that the percentage of eggs which fail to hatch increases with the number of pods present in the egg-laying tube and when six or seven pods were laid in one tube, none of the eggs hatched.

The egg of G. transversus Thunb. increase in size during embryonic development, as has been reported in Locusta migratoria (Roonwal, 1936), Melanoplus differentialis (Slifer, 1937) and Schistocerca gregaria (Roonwal, 1953), while the eggs of Tmethis do not undergo any change in size (Shulov, 1952d).

Hatching is of general acridoid pattern.

The vermiform larva of G. transversus Thunb. is enclosed in a thick cuticular membrane. The larva later on casts its outer covering and this casting is termed as "intermediate moult". Some authors have not considered this intermediate moult to be a true one but since the present author has not found any important difference between this and the subsequent moults, he is therefore, inclined to agree with the findings of Uvarov (1966).

No diapause occurs at any stage of the life-cycle of G. transversus Thunb. and it is possible to obtain four generations

in a year in the laboratory. Golding (1948) from field observations reports that in G. africanus an egg-diapause occurs during the dry season in Nigeria, adults first appearing during late June in North East and October in the South West. Descamps (1953) confirmed the existence of egg-diapause in Gastrimargus from French Equatorial Africa, but also suggested that sometimes , it is possible to obtain two generationsa year. Antoniou and Hunter-Jones(1956) have found that 3 generations of E. capitata can be obtained under laboratory conditions. But Khalifa (1957) reported E. plorans in Egypt has only one generation in a year and eggs hibernate.

Observations made on G. transversus Thunb. go to suggest that there seems to be no obligatory diapause in this insect since 4 generations under constant temperature and humidity conditions could be obtained in a year. The non-viability of about 20 per cent egg-pods and a certain percentage of non-viable eggs in a viable egg-pod can not be considered as a positive proof of these eggs undergoing diapause. It could also not be ascertained as to why these egg did not hatch at all while others under similar ecological conditions produced normal larvae. Their failure may be assigned to a variety of mechanical and physiological reasons which could only be established by subjecting these eggs to sectioning in order to ascertain whether any development has been initiated at all. This being out of scope of this finding has been excluded from the present observations.

A variation has been recorded in the number of hopper instars among the isolated hoppers, varying from 4-6 instars in males and 6-7 instars in females. Similar variation in the number of hopper instars has also been recorded in its allied species G. africanus Sauss. by Hunter-Jones and Ward (1959), but there it varies from 4-6 instars only. Kevan (1943) has attributed this variation to the size of the adult parents, while partially agreeing with the observations of Kevan (1943) it may be pointed that certain experiments are in progress keeping certain ecological factors in view and the result shall be published at a later date.

The variation in colour and its pattern among the hoppers has also been recorded from one instar to another and in the same instar as well. Similar variation in colour and its pattern has also been recorded among the hoppers of G. africanus Sauss. by Hunter-Jones and Ward (1959) and has been correlated with the black background, food and humidity, but the present author agreeing with Hunter-Jones and Ward (1959) also suggests rearing density as one of the affecting factors.

4. SUMMARY

C. transversus Thunb. primarily is a pest of cereals, millets and bamboos etc. Beside these, it also attacks weeds, vegetables and nursery plants. It occurs throughout tropical Africa, Sudan, South Africa, United Provinces, Nepal, Baltistan, Shevaroy Hills, Celebes, Sylhet and India. In India it is distributed in West Bengal, Madras, Assam, Kashmir, Ladakh, Garhwal, Aligarh etc. The adults and hoppers are gregarious and are found in masses. They were collected from the Acridian Experimental Field Station at Aligarh. The bionomics and its life-history has been studied in the constant temperature room at 32 ± 1°C and 65 ± 5% R.H. where 12 hours' light altered with 12 hours' darkness. The insects were fed on the *Cynodon dactylon* leaves. The results are summarised as below.

The adults are of variable colour, may be brown or green with dark brown, black and yellowish bands or patches on the body. The hind tibiae are red. The adults emit an offensive secretion when they are caught. The female is larger in size than male. The male and female do not mature at the same time. The pre-copulation period is 6.8 ± 0.249 days in males and 8.7 ± 0.338 days in females. Copulation is of acridian type but the copulating pairs show different postures during copulation. The process of copulation lasts for about 30-50 minutes. The female starts oviposition on an average of 6.2 ± 0.333 days and lasts for 30-60

minutes. The average oviposition and post-oviposition periods are 16.9 ± 1.493 and 2.0 ± 0.421 days respectively. The maturation period and egg-laying rate remains the same under isolated and crowded conditions, but crowding affects the average fecundity and fertility of eggs. In the isolated adults the average fecundity is higher than those of crowded adults.

The egg-pods are more or less cylindrical in shape measuring 4-6.5 cm in length and 0.5-0.7 cm in diameter. The average number of egg-pods laid by an isolated and crowded females is 4.1 ± 0.457 and 3.8 ± 0.302 pods respectively. The average number of eggs per pod is 46.5 ± 3.948 and 39.52 ± 3.102 in isolated and crowded conditions respectively. The freshly laid eggs are pale yellow changing to light brown, measuring 0.55 cm in length and 0.12 cm in diameter. The average incubation period is 18.0 ± 0.311 days. There is variation in the number of hopper instars varying from 4-6 in males and 6-7 in females. Similarly colour variations have also been recorded among the hoppers of different instars as well as in the same instar.

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